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ABSTRACT

This syllabus begins with a list of program objectives and performance criteria for the study of three general topic areas in earth science and a list of 22 science processes. Following this information is a listing of concepts and understandings for subtopics within the general topic areas: (1) the earth's surface--surface features, rock fragments and bedrock, minerals (identification, formation, economic uses), rocks (igneous, sedimentary, metamorphic), oceans (extent/depth, shape of ocean floor, composition of sea water, economic importance of oceans), topographic maps (location/direction, distance, relief), and aerial photographs; (2) changes in earth's survace--destructional forces (weathering, erosion), constructional forces (earth movements, major landforms), and vulcanism (extrusive, intrusive); and (3) age of the earth-- the rock record (fossil content, rock sequence, crustal processes, radioactive dating) and the earth's history (age of the earth, earth's beginning, geologic history). Questions and activities corresponding to these concepts and understandings are keyed to a list of science activities presented in an appendix. These activities are also keyed to one or more of the processes listed at the beginning of the syllabus. Charts, tables, and diagrams (containing keys to common minerals and rocks and other information) are included in a second appendix. (JN)

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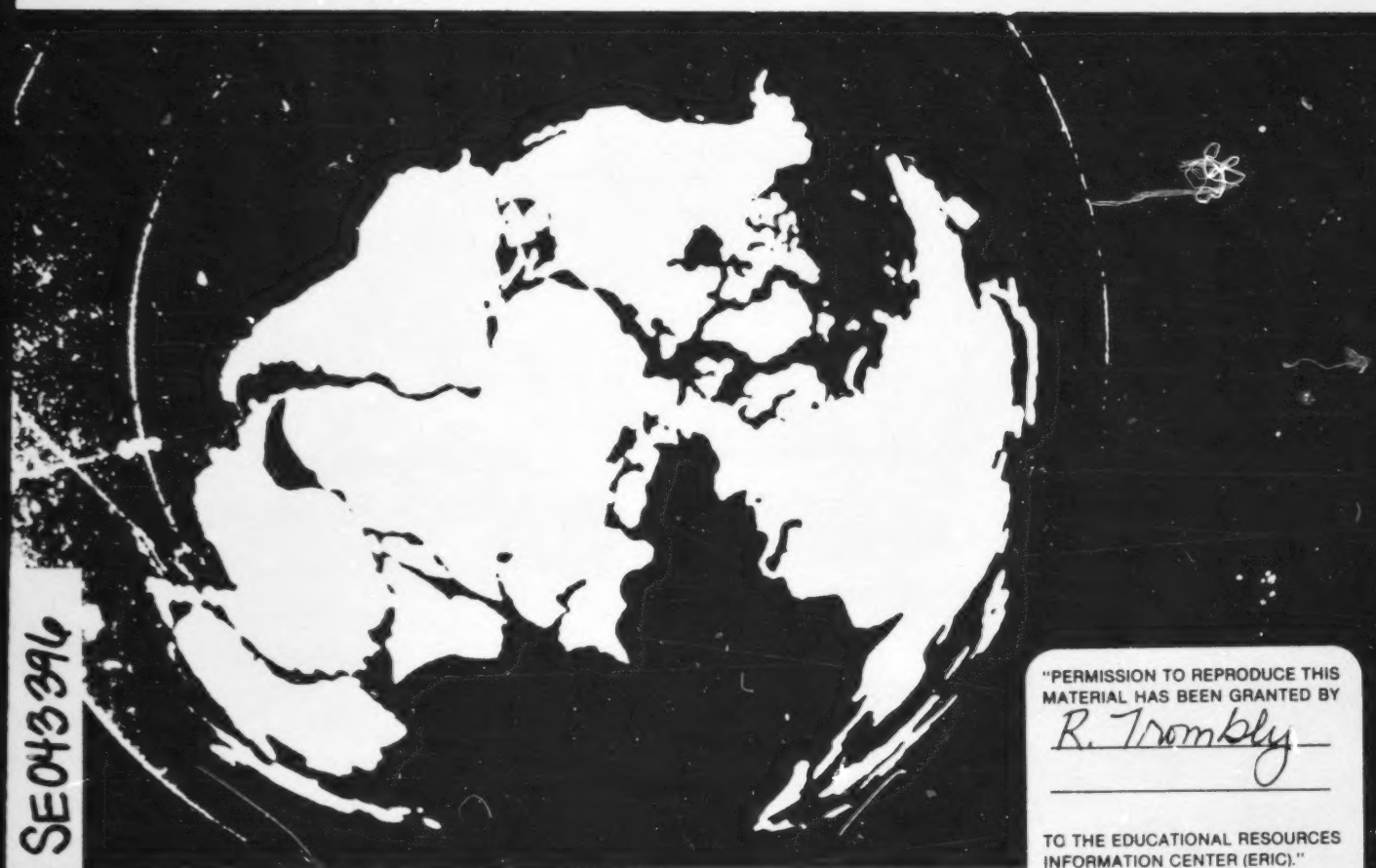
THE EARTH'S CHANGING



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Science Syllabus for Middle and Junior High Schools

THE EARTH'S CHANGING

THE EARTH'S CHANGING SURFACE

block D

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FOREWORD

This publication is the fifth product of the project to significantly update and reorder the Science Syllabus for Middle and Junior High Schools. When completed the project will result in a group of instructional blocks encompassing the content and skills in the biological, physical, and earth sciences appropriate for the grade levels indicated above.

The understandings, questions, and learning activities in the publication have been enhanced by the inclusion and referencing of program objectives, performance criteria, and process skills which serve to focus student achievement. Thus, environmental considerations are infused throughout the content material and the importance of consumer and career implications in a science program is specifically acknowledged.

The objectives and performance criteria are provided in a general outline on pages 1 through 3 which conforms to the content subdivisions in the publication; the process skills are keyed to the learning activities; and the learning activities are keyed to the understandings and the questions.

The development of this syllabus was coordinated within the Bureau of General Education Curriculum Development by Barry W. Jamason, associate. David M. Berey, Roslyn Public Schools, revised portions of the content material while reviewing the entire manuscript. Edward T. Lalor, Chief, Bureau of Science Education, and Douglas S. Reynolds, associate in science education, reviewed all materials and made valuable suggestions for content improvement and accuracy. The cover design was created by Oscar A. Kaufman.

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PROGRAM OBJECTIVES AND PERFORMANCE CRITERIA

The program objectives and performance criteria below are provided as an aid in ordering the direction and synthesizing the outcomes of the instruction related to this block. The objectives and outcomes (performance) described below for this program are merely illustrative, and, as such, they permit latitude in the selection of additional content. It is implied that student knowledge, understanding, and skills accrued as a result of content selection and instruction will be demonstrable in the manner, and to the minimum extent, described.

Program Objectives	*Performance Criteria*
I. THE EARTH'S SURFACE	
The student will be able to describe the action of the opposing forces that result in the surface features of the earth.	Given a feature of the earth's surface, the student will be able to classify the forces which contributed to its formation as destructional or constructional.
The student will be able to identify the physical and chemical properties used to identify minerals and describe the process of mineral formation as it relates to the nonrenewability of these resources.	Given an appropriate mineral, the student will be able to name the physical and chemical properties which should be examined in order to identify it.
	Given an appropriate mineral, the student will be able to describe the processes which led to its formation.
	Given an appropriate mineral, the student will be able to describe those processes which relate to its nonrenewability.
The student will be able to name the three major classifications of rocks and describe how each was (is) formed.	Given an appropriate rock sample, the student will be able to describe the processes that led to its formation.
The student will be able to classify rocks as igneous, metamorphic, or sedimentary.	Given an appropriate rock sample, the student will be able to classify it as igneous, metamorphic, or sedimentary.
The student will be able to state the extent and average depth of the oceans, and assess the reasons for their importance.	Given an opportunity, the student will be able to describe the extent, depth and shape of the oceans, their composition, and their economic importance.

Program Objectives	*Performance Criteria*
The student will be able to use a topographic map to contrast the location and elevation of the land features of two different locations.	Given a topographic map, the student will be able to locate a point, determine its elevation, and describe the land features surrounding it. Given two locations on a topographic map, the student will be able to measure the distance between them and to contrast their respective elevations and the land features surrounding them.

II. CHANGES IN THE EARTH'S SURFACE

The student will be able to describe the destructional forces of weathering and erosion as they effect the movement of continental material.	Given a land feature, typically formed by destructional forces, the student will be able to describe the actions of physical, chemical, and biological weathering that contributed to its formation. Given a land feature typically formed by destructional forces, the student will be able to describe the erosional effects of water, wind, and glaciers that contributed to its formation.
The student will be able to describe the constructional forces that cause movement of the earth's crust and cite the evidences of these forces.	Given a land feature formed entirely or in part by constructional forces, the student will be able to describe the evidences and possible causes of its formation.

III. THE AGE OF THE EARTH

The student will be able to explain the inferences made in the study of composition, sequence, and fossil content of rocks which are used in describing the rock record.	Given a theory which describes the past history of the earth, the student will be able to describe the inferences, observations, and hypotheses which support the theory.
The student will be able to describe the major hypotheses used to explain the earth's age and history.	Given an opportunity, the student will be able to explain the hypotheses proposed to explain the earth's formation.

Program Objectives	*Performance Criteria*
Throughout this program, the instructor should be cognizant of the importance of including several related objectives and performance criteria which represent the practical infusion of career and consumer considerations as they relate to science education.	
The student will be able to describe the economic and esthetic importance of landforms as they relate to recreation, natural resources, and the concepts of interdependence, balance, survival, and conservation.	Given a case study relating to the economic and/or esthetic use of land or water, the student will describe the opportunities and limitations involved in the choices to be made. Given a natural resource, the student will be able to characterize the resource in terms of economic importance, availability, renewability, and significance to human and other biotic activity. Given an appropriate land form, the student will be able to relate its potential for esthetic and economic use.

PROCESSES

One of the major objectives in all science courses is the development of competence in processes used in science. The learning activities in this publication will assist students in attaining this objective. Each activity is keyed to one or more of the processes listed below. For example, activity (D-1) involves processes [1], [2], and [14]. In general, the processes are listed in order of predominance within the activity and appear to the right of the activity's title.

[1] Observing objects and phenomena

[2] Describing observations

[3] Selecting suitable measuring instruments

[4] Developing skills in using laboratory equipment

[5] Measuring objects and phenomena

[6] Performing laboratory techniques

[7] Estimating measurements within limits of accuracy

[8] Recognizing a problem

[9] Formulating a working hypothesis

[10] Designing appropriate tests of a hypothesis

[11] Designing suitable procedures for experimental tests

[12] Processing experimental data

[13] Organizing data to show a functional relationship

[14] Interpreting observations and data

[15] Interpolating and extrapolating

[16] Evaluating a hypothesis in the light of data obtained

[17] Formulating generalizations based on relationships

[18] Recognizing the need for a theoretical model

[19] Formulating a theoretical model to accommodate knowledge

[20] Designing relationships satisfied by a model

[21] Deducing a hypothesis from a theoretical model

[22] Interpreting and evaluating tests of a model

[23] Producing a revised, refined, or extended model

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
I The Earth's Surface	
The surface features of the earth are continually undergoing change.	*What are some evidences that show that the surface of the earth is continually undergoing change?* (D-1)
A Surface features	
The earth's surface features result from the orderly action of two sets of opposing forces—destructional and constructional.	
The destructional forces, which include weathering and erosion, wear down and remove existing land features.	
The constructional forces, which include movements of the earth's crust and vulcanism (diastrophism), raise the crust and form new land features.	
B Rock fragments and bedrock	
The earth's surface consists of soil, rock fragments, and solid bedrock.[1]	
Most of the land surface of the earth is covered by soil or rock fragments.[2]	
Soil and rock fragments are formed by the breaking down of bedrock. Soil consists of weathered rock fragments that contain organic material.	
C Minerals	
The solid crust of the earth is composed of rock-forming minerals.[3]	*How do minerals differ from rocks?* (D-2)

---

[1] If bedrock is found at the surface it is called an outcrop. Bedrock can often be seen at the surface in mountains, cliffs, and roadcuts.

[2] Solid rock fragments are found overlying solid bedrock. Loose rock fragments may range from giant boulders to tiny grains.

[3] The earth's crust varies in thickness from about 8 km under the oceans to about 40 km under the continents.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
A mineral is a naturally occurring element or inorganic compound.[4]	
The eight most common elements of the earth's crust in decreasing order of abundance by weight are oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium. These eight elements by weight make up 98 percent of the earth's crust.	
Over 2,000 minerals are known, but only a few (about 10) make up most of the earth's crust.[5]	
1 identification	
Minerals are identified by some of their physical and chemical properties.[6]	*How can an unknown mineral be identified?* (D-3)
a physical properties	
(1) hardness	
Hardness is the ability to resist scratching.	*How can the hardness of a mineral be established?* (D-4)
(2) breakage	
(a) cleavage	
Some minerals break in definite directions along smooth surfaces known as cleavage planes or faces. Minerals may have one, two, three, four, or as many as six directions of cleavage.[7]	*How can the cleavage or fracture of a mineral be determined?* (D-5)

---

[4]Minerals are homogeneous inorganic substances which usually have specific chemical compositions and fairly definite physical properties. The composition of some minerals can vary slightly within a restricted range.

A few minerals occur as elements such as sulfur, copper, silver, and gold, but the great majority are compounds of two or more elements.

[5]The two most abundant mineral compounds, feldspar and quartz, make up more than half of the earth's crust.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(b) fracture	
A mineral may break (fracture), leaving an irregular surface.	
(3) streak	
Streak is the color of the fine powder of a mineral and may differ from the surface color of the mineral.[8]	*How can the streak of a mineral be determined?* (D-6)
(4) luster	
Minerals reflect light in different ways. A mineral has either a metallic or nonmetallic luster according to whether or not it reflects light like the surface of metal.[9]	*How can the luster of a mineral be determined?* (D-7)
(5) color	
Color is a poor basis for identification since many minerals are colored by impurities.[10]	*How can the color of a mineral be determined?* (D-8)
(6) crystal form	
Most minerals possess a definite geometrical shape.[11]	*How are crystals of a mineral formed?* (D-9)
(7) density	
Density is the ratio of the mass of a substance to its volume. The density of a uniform substance is the same regardless of the size or shape of the sample.[12]	*How can the density of a mineral be determined?* (D-10)

---

[6]Most minerals have only a few distinctive physical properties which aid in their identification as shown in the chart in Appendix B (pages 68-9 [1]).

Most common minerals may be identified by physical properties alone, but some require detailed chemical analysis, x-ray analysis, or optical analysis for final identification.

[7]The arrangement of the atoms and the types of bonds in a given mineral determines whether it will break regularly (cleavage) or irregularly (fracture).

[8]A mineral is usually powdered by rubbing it on a piece of unglazed porcelain (streak plate). Minerals harder than 6.5 will not produce a streak on porcelain, but will scratch it instead.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
b chemical properties	
(1) acid test	
If the mineral is a carbonate, a bubbling reaction due to the release of carbon dioxide gas results when dilute hydrochloric acid is placed in contact with the mineral.	*How can the presence of a carbonate be detected in a mineral?* (D-11)
2 formation	
Most minerals are formed far below the earth's surface.	
a cooling and hardening of magma	
Minerals crystallize when magma cools.[13]	*How do minerals appear when they have crystallized from a melt?* (D-12)
b evaporation of bodies of water	
Minerals are deposited from solution when natural bodies of water evaporate.[14]	*How can deposition of minerals by evaporation be illustrated?* (D-13)
c chemical weathering	
New minerals may form from the chemical weathering of rock as in the case of feldspar to clay.	
3 economic uses	
For all practical purposes, minerals are nonrenewable resources. The future existence and the standard of living of the human race depend upon the wise use of these resources.[15]	*How are our natural resources used and conserved?* (D-14)
The prosperity of a nation is greatly influenced by the amount, variety, availability, and utilization of its mineral resources.	

Streak is the true color of a mineral and is helpful in identifying ore minerals. Impurities that alter the color of a mineral do not affect the streak.

[9]Luster should be determined from a freshly-broken surface. Types of nonmetallic luster include dull, silky, pearly, waxy, greasy, vitreous (glassy), and adamantine (diamond-like).

[10]Color should be observed from a fresh, untarnished surface. Few minerals have a single color that never varies. The presence of impurities can produce different varieties of the same mineral.

[11]X-ray photographs show that crystal forms are determined by internal atomic arrangement. Not all samples of a mineral readily show the

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
D Rocks	
The crust of the earth is composed of rocks which are naturally occurring substances composed of one or more minerals.[16]	*How may rocks be collected and described?* (D-15)
Rocks are classified according to origin into three groups: igneous, sedimentary, and metamorphic.[17]	*What is the rock cycle? (See Appendix B, page 70 [2].)*
1 igneous	
a formation	
Igneous rocks form through the cooling and hardening of hot molten material above or below the earth's surface.	
Some igneous rocks (extrusive) form when hot molten material breaks through the earth's surface, as when a volcano erupts.	
Some igneous rocks (intrusive) form far beneath the surface and are exposed after the overlying rock has eroded.	
b identifying characteristics	
Igneous rocks which cooled quickly have small crystals or no crystals at all (are glassy); Igneous rocks which cooled slowly have large crystals.[18]	*How do igneous rocks form?* (D-16)
	How can igneous rocks be identified? (D-17)
2 sedimentary	
a formation	
Most sedimentary rocks are made up of rock fragments broken away from other rocks, then transported by water, wind, or	*How can artificial sedimentary rocks be produced in the laboratory?* (D-18)

crystal form. As a result, crystal form is often of little help in identifying a mineral.

[12]Density depends upon the nature of the atoms in the mineral (some atoms are much heavier than others), and the spacing of the atoms (the closer the atoms, the greater the density).

[13]The two most common minerals, feldspar and quartz, are formed by the cooling of magma.

[14]Rock salt, gypsum, and borax are minerals that were once in solution in lakes and oceans. Salt and gypsum occur in large quantities in central and western New York State respectively.

glaciers to new locations in water or on land where they reassemble.

Some sedimentary rocks form from compounds precipitated chemically or with the aid of organisms from sea water. These sedimentary rocks are called evaporites.[19]

b identifying characteristics

Many sedimentary rocks have the appearance of grains cemented together while evaporites appear to be crystalline.

How can sedimentary rocks be identified? (D-19)

3 metamorphic

a formation

Metamorphic rocks are formed when rocks are altered by heat, pressure, chemical action, or any combination of these.[20]

b identifying characteristics

Some metamorphic rocks show a banded appearance. Heat and pressure can cause different minerals to separate into layers.

How can metamorphic rocks be identified? (D-20)

E The oceans

1 extent and depth

The oceans cover nearly three-quarters of the earth's surface, mostly in the Southern Hemisphere.

The average depth of the oceans is about 4 kilometers, while the greatest depth is about 11 kilometers.[21]

How do scientists study the ocean? (D-21)

---

[15]It is particularly important to stress the concept of conservation. If policies and procedures are not changed, we will, in the forseeable future, exhaust the world supply of many nonrenewable resources.

[16]Granite and basalt are the two most abundant rocks in the earth's crust.

[17]All rock was probably originally igneous. By weight, more than 90 percent of the earth's crust is composed of igneous rocks or metamorphosed igneous rocks.

[18]Granite and shale are examples of rocks composed of several minerals. Limestone, marble, and rock salt contain only one mineral. On the other hand, coal is comprised primarily of materials which are not mineral.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
2 shape of the ocean floor	
The floor of the ocean resembles the major landforms of the continents and has mountains, valleys, plains, and plateaus.[22]	*What is the shape of the ocean floor?* (D-22)
a continental shelves	
From the shoreline, continental shelves slope gently out into the oceans to an average depth of about 150 meters.	
Continental shelves are formed by material eroded from the land by running water and deposited offshore.	
b basins	
Ridges, valleys, and deeps are found in the basins.[23]	
3 composition of sea water	
Sea water contains about 96 percent water and 4 percent salts.[24]	*Why does the water cycle cause the oceans to become saltier?* (D-23)
Carbon dioxide and oxygen are dissolved in sea water.	
4 economic importance of the oceans	
The oceans are the great reservoir of water which serves humankind in many ways.	*What are the mineral resources of the ocean?* (D-24)
The oceans are economically important because they may provide desalinated water for agricultural and domestic purposes, are a source of food,[25] serve as a modifier of temperature,[26] and are the repository for most of the minerals that have drained off the land since the beginning of the Earth.[27]	

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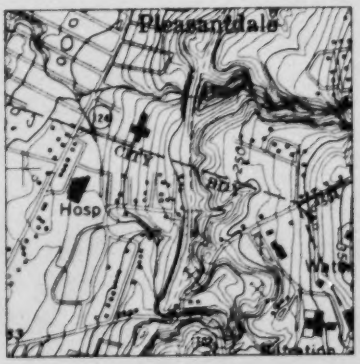
[18]Basalt is a fine-grained igneous rock while granite is coarse-grained.

[19]Sedimentary rocks cover about 75 percent of the earth's surface area, but represent only about 5 percent of the crust. Most sedimentary rock is formed under water. Shale, sandstone, and limestone make up about 99 percent of all sedimentary rocks. Shale is the most abundant and limestone is the least abundant.

[20]If the heat and pressure are too great, the rock will completely melt and igneous rock, rather than metamorphic, will result.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
F Topographic maps	
A topographic map is the representation of a three-dimensional portion of the earth's surface on a plane (two dimensions).[28]	*How can three dimensions of the earth's surface be represented on a plane?* (D-25)
1 location and direction	
Topographic maps contain much information and differ from other maps mainly in showing relief by contour lines. They are bounded on the north (top) and south by parallels of latitude and on the east and west by meridians of longitude.[29]	*What information can be obtained from topographic maps?* (D-26)
	What is a quadrangle? (D-27)
2 distance	
Distance is determined on the map by means of a scale. The scale is the ratio between a map distance and the same distance measured on the ground.	
3 relief	
Relief is the difference in elevation between the high and low points of a land surface; it can be determined from contour lines on a map.	



[21]The oceans are much deeper than continents are high. The average height of the land is 0.8 kilometer. The Marianas Trench, a trough about 11,582 meters deep near the Philippine Islands, is thought to be the ocean's deepest spot.

The depth is automatically determined and recorded by an echo recorder. A sound is transmitted from the ship and the time it takes to reach the bottom and be reflected back to the ship is measured. Knowing this time and the average speed of sound in water, it is possible to calculate the depth of the ocean at that point.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
a contour line	
A contour line is a line on a map connecting points of equal elevation above sea level.	*How can relief be represented accurately on a two-dimensional surface?* (D-28, D-29)
All points on a given contour line have the same elevation.	
Contour lines never cross one another.	*How can the contours of the land be measured?* (D-30)
A steep slope is representated by closely spaced contour lines; a gentle slope by widely spaced contour lines.	
Uniformly spaced contour lines represent a uniform slope.	
Contour lines curve in an upstream direction when crossing a valley.	
The lowest elevation is usually on the major stream where it leaves the map.	
b contour interval	
A contour interval is the difference in elevation between two adjacent contour lines.	
Contour lines are drawn at a fixed elevation interval for a particular map.[30]	
c topographic profile	
A topographic profile is a vertical profile showing the rise and fall of the land surface along a selected line on the map.[31]	*How can a topographic profile be constructed?* (D-31)

[22]The continuous recording of depth beneath a moving ship gives a vertical profile of the shape of the ocean floor along the line of travel.

[23]The Mid-Atlantic Ridge, about 300 kilometers wide and 17,000 kilometers long, extends along the entire bottom of the Atlantic Ocean. The Azores are a part of this ridge.

[24]About 75 percent by weight of the dissolved salts is common salt (sodium chloride). The sea is getting saltier because the streams continue to bring more salt from the land, while evaporation carries away only fresh water.

[25]A knowledge of ocean currents is helpful in predicting the locations where fish exist in large numbers.

G Aerial photographs

Aerial photographs permit three-dimensional viewing of an area. Differences in relief can be determined using aerial photographs.[32]

II Changes in the Earth's Surface

A Destructional forces

Forces are at work constantly to move material from the continents into the ocean basins; such forces are destructional forces.

1 weathering

Rocks at or near the earth's surface crumble and decay when exposed to the atmosphere. This weathering, which may be either physical or chemical, produces rock fragments on the surface of the earth. Continued weathering of the exposed rock fragments produces soil necessary to agriculture.[33]

How do rocks weather? (D-32)

What is the composition of soil? (D-33)

a physical

Physical weathering is the breaking of rock without any change in its chemical composition.

What are some physical weathering processes? (D-34)

(1) freezing

When water freezes in the cracks of rocks, it expands and breaks the rocks.[34]

(2) expansion and contraction

Large temperature changes (unequal cooling) may cause different minerals which expand and contract at different rates to break apart.

Also, research is being conducted on growing algae as food for humans to alleviate the growing food shortage.

In certain areas deep sea water rich in minerals rises to the surface. The minerals serve as food for plankton which in turn provide food for fish.

[26]Ocean currents tend to move warm water from the tropics to the polar regions and cold water in the opposite direction. Coastal areas tend to be warmer in winter and cooler in summer than inland areas of the same latitude. This occurs because of the high specific heat of water compared to land materials. This results in the water being warmer in winter and cooler in summer than adjacent land.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
b chemical	
Chemical weathering is the breaking of rock accompanied by a change in chemical composition.	*What are some chemical weathering processes?* (D-35)
(1) oxygen	
Oxygen combines with minerals when they are wet, forming new compounds which are less able to hold the rock together.[35]	
(2) solution	
Water can dissolve some minerals in rocks.	
(3) carbon dioxide	
Water combines with carbon dioxide of the air to form carbonic acid, which reacts with many rocks forming soluble compounds.[36]	
(4) decaying animal and vegetable matter	
Acids produced from organic substances can dissolve minerals in rocks and cause others to crumble and fall apart	
c biological	
Rocks are broken by living plants and animals.	*What are some biological weathering processes?* (D-36)
(1) wedge work of roots	
Plant roots growing between the cracks in rocks exerts pressure which can cause further cracking.	

Surface ocean currents are caused mainly by winds and follow paths similar to those of the major wind belts. The direction of surface ocean currents is also influenced by water density differences. The density differences are caused by differences in water temperature and salinity.

[27]Many important minerals are found in great abundance in the oceans. Magnesium and bromine are obtained commercially from salts found in sea water. They are removed from their compounds by electrolysis. Both sea water and the ocean floor are relatively untapped sources of great mineral wealth. Research is continuing on methods of seawater

(2) lichen and mosses

Some plants grow on rocks and split their surfaces.

d factors influencing weathering

The rate of weathering depends upon the physical and chemical properties of the rocks, the climate, and the amount of rocks exposed to the elements.

Weathering is most pronounced in regions having a moist climate with hot summers and cold winters.

e soil

Soil is a product of both physical and chemical weathering processes

(1) formation

Soil forms from rock fragments by the slow processes of weathering, accompanied by the growth and influence of living things.

How is soil formed? (D-37)

(2) composition

Soil is composed mainly of minerals, water, and organic compounds.

Each soil, of the hundreds worldwide, is the product of a particular combination of climate, living matter, slope and chemical composition of the underlying rock, and the length of weathering.

(3) classification

Soils are classified according to climate and the type of vegetation.[37]

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extraction and sea floor mining. Economics may some day stimulate far greater use of the oceans' mineral resources.

[28]The use of topographic maps can aid in the study of regional landscapes. They are most effective when used in conjunction with other aids such as photographs, slides, films, and aerial photographs. (See Appendix A, pages 42-9.)

[29]The map area enclosed by lines of latitude and longitude is called a quadrangle. Each quadrangle is named for an important town or topographic feature within the area.

[30]Contour intervals selected for maps depend on relief. Small contour

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(4) relation to plant growth	
Soil productivity depends on the fertility and the physical condition of the soil.[38]	
Continued productivity of the soil depends upon returning to the soil minerals removed by plant growth.	
2 erosion	
a ground water	
Ground water is that part of rainfall which sinks into the ground.	
(1) relation to the water cycle	
The entire earth's water supply follows the endless cycle of evaporation or transpiration, precipitation, runoff, and storage.	
(2) relation to erosion	
Ground water moves slowly and erodes mainly by dissolving material or producing a chemical change to form a soluble substance.	
(a) destructive action	
Ground water, if slightly acid, will dissolve limestone bedrock, forming caves.	*How can ground water erode limestone?* (D-38)
(b) constructive action	
Limestone (or other material) dissolved in ground water may come out of solution and form deposits above and below the surface.	*How are limestone deposits formed?* (D-39)
Stalactites and stalagmites are limestone deposits often found in limestone caves.	

intervals are used for flat terrain; larger intervals for mountain areas.

[31]This profile may be difficult for some pupils to visualize. It should be helpful if one is drawn for a local area. The profile can be used effectively later when studying landforms.

[32]When viewing aerial photographs through a stereoscope, relief is exaggerated. Relative difference, however, can still be determined.

[33]Gravity has an effect upon the speed of weathering. Parts of rocks which have been broken apart may fall and expose new surfaces to the elements. Landslides and

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(3) relation to water for human use	
Ground water is one of the most important natural resources.	
The amount of it in an area depends upon the amount of precipitation, the nature of the surface rock materials and bedrock, and the amount of water used by humans.	
Ground water moves by gravity through rocks to the lowest levels of the land - toward streams, lakes, and oceans.	
(a) the water table	
The water table is the level below which rocks or rock fragments are saturated with water.	*What is the water table?* (D-40)
Rocks vary in their ability to absorb and hold water.[39]	*How do rocks vary in their ability to absorb and hold water?* (D-41)
The ability of a rock to hold water depends upon the amount, size, and arrangement of the pore spaces.	
(b) conservation	
Conservation of ground water is a national and world problem.	*Describe your community's water supply and any local water conservation efforts. What is the quality of this water? How is waste water treated?*
b running water	
Running water causes most of the erosion on the earth's surface.[40]	

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hillside creep are examples in which gravity keeps rock exposed to weathering.

[34]Freezing (frost action) accounts for considerable weathering in New York State. This may be obvious in winter near roadcuts marked "Fallen Rock Zone."

[35]This is analagous to the rusting of iron which is not a rock. The iron oxide has different properties than iron.

[36]This chemical change accounts for the formation of limestone caves.

[37]Soils in temperate, humid climates with a forest cover are light-colored with a dark, organic upper

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(1) work of streams	
Running water removes rock material from higher elevations and transports it to lower elevations where deposition occurs.	*What are some characteristics of a local stream that can be observed?* (D-42)
(a) stream erosion	
Running water erodes by wearing away, by friction (abrasion), and by solution.	*What are some stream characteristics that can be illustrated with a stream table?* (D-43)
The rate of erosion depends upon the velocity and volume of a river. The nature of the material transported also affects the rate of erosion. Hard materials, like quartz, will rapidly cut through the stream bed.	
The lowest level that a river can erode is the level of the body of water into which the river flows. For rivers that empty into the ocean, base level is sea level.	
(b) transportation of rock material	
The amount and size of the materials moved depends upon the volume and velocity of the water.	*How is the load of a stream affected by water volume and velocity?* (D-44)
Rivers carry materials in suspension, in solution, or by rolling along the river bed. A stream carries most of its materials in suspension.	
(c) deposition of rock materials	
With a decrease in velocity, a stream deposits rock material.[41]	*How is material deposited by running water?* (D-45)

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surface. Subhumid climates with grasslands promote dark-colored soils high in organic matter. Light-colored soils, rich in carbonates, form in shrub-covered, arid regions.

[38] Gray and yellow surface soils are low in natural productivity. Red surface soils are commonly more productive, but brown and black soils have the greatest natural fertility.

[39] Although clay has about twice the pore space as an equal volume of sand, it is quite impermeable because the pores are very small.

[40] Streams and their effects should be studied as much as possible by direct observation.

[41] A brief reference may be made to the fertility of the soil of the deltas of principal rivers of the

(2) formation of a valley

Over a period of time, streams lengthen, widen, and lower their valleys.[42]

How does a river valley develop? (D-46)

(3) life history

Streams pass through a series of stages in their development.

A young river has a rapid velocity, a V-shaped valley, few tributaries, wide interstream areas, and poor drainage.

A mature river has a decreased velocity, a wider valley, many tributaries, narrow interstream areas, flood plains, and good drainage.

An old age river has a small velocity, a very wide valley, and very wide flood plains.

(4) retarding erosion by running water

Erosion by running water is a natural process and occurs whenever water moves from any elevation toward sea level. It cannot be stopped, but its speed may be slowed.

Conservation of many of our natural resources depends largely upon slowing the rate of erosion by reducing the volume and/or velocity of the water.

c wind

The wind changes the surface of the land, particularly in arid regions.

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world. Deltas are not unusual and occur when a stream enters most large bodies.

[42]Rainwater, helped by gravity, removes loose material at the source of a stream to form miniature valleys called gullies. Streams lengthen their valleys in an upstream direction through the growth of gullies.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(1) regions of wind activity	
Wind blows everywhere but it is an important erosive agent only in deserts, along shorelines, and in fields not protected with vegetation.	
(2) work of wind	
Wind removes earth material and deposits some of it.	*What is the evidence that wind transports material?* (D-47)
(a) wind erosion	
High winds will blow away loose soil and rock particles. Wind-blown sand and dust scratches and breaks up solid rock.	
(b) transportation of dust	
In cultivated, semiarid regions, strong winds often produce dust storms.	
(c) wind deposits	
Dunes, the most common of wind deposits, are mobile hills of sand.[43]	*How are sand dunes formed?* (D-48)
d glaciers	
A glacier is a mass of ice formed by the recrystallization of snow and which flows, or at some time has flowed.	
(1) occurrence	
Glaciers form where winter snowfall exceeds summer melting. Freezing and thawing and increasing pressure change the accumulated snow to ice.[44]	

[43]Sand dune shapes indicate wind direction. The side facing the wind (windward side) has a low gentle slope; the side sheltered from the wind (leeward side) is short and steep.

[44]Glaciers now cover about 10 percent of the earth's land area and are mostly in high latitudes. The changing of snow to ice is accomplished in much the same manner as making icy snowballs. The pressure reduces the freezing point and melting occurs. A reduction in pressure causes the freezing point to rise and the water freezes.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(2) types of glaciers	
(a) valley	
Valley glaciers form in mountain valleys which descend from high mountain areas.	
(b) continental	
Continental glaciers are thousands of meters thick and cover large areas, burying hills and valleys.	
(3) glacier movement	
Glaciers move in response to gravity a few centimeters to as much as 1 meter per day.	*How do glaciers move?* (D-49)
(4) work of glaciers	
Moving ice, carrying rock fragments as cutting tools, erodes the surface over which it passes.	*How do glaciers erode?* (D-50)
Valley glaciers create rugged terrain by removing rocks from steep slopes, while continental glaciers level the land by removal or deposition of rock.	
(5) erosional features	
Glaciers produce striations or scratches on the rocks over which they move and indicate direction in which the glacier is moving. Other features produced include U-shaped valleys, hanging valleys, cirques, and matterhorns.[45]	*What are some glacial features that can be observed?* (D-51)

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[45] The ice erodes both the bottom and sides of a valley to produce a U-shape.

When a tributary glacier erodes slower than the main glacier, a hanging valley (and waterfalls) results when the glacier retreats.

A cirque is a steep-sided, bowl-shaped basin that forms at the upper end of a glacial valley. When three or more cirques close together erode rock at high elevations, a sharp, pyramid-shaped mountain peak called a matterhorn will develop.

(6) depositional features

Glacial deposits form when the ice melts and the rock material is released.

(a) moraines

When a glacier melts, it deposits moraine in irregular piles.[46]

(b) outwash plain

A broad, gently sloping deposit may be formed beyond the terminal moraine by streams from the melting ice.

(c) other features

Drumlins, kames, kettles, tarns, and eskers are formed by glaciers.

(7) the Ice Age

Largely inexplicable decrease in average temperature and/or increased precipitation resulted in the Ice Age.

Continental glaciers have advanced and retreated four times in the last 1 million years.

The southern limit of the continental glacier followed a line from Long Island, west along the Ohio and Missouri Rivers. A marked contrast in topography exists north and south of that line.

Much of the topography of New York State is the direct result of glaciation, the last glacier having retreated from New York State about 11,000 years ago.

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[46] Moraines are described as terminal, lateral, or medial according to the deposition location of the material in the glacier as at the front, side, or middle, respectively.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
e waves and shore currents	
Ocean waves result from the friction produced when wind blows over the surface of the water.[47]	*How does water in an ocean wave move?* (D-52)
In water wave motion, the wave moves forward, but the water moves chiefly up and down.	
Longshore currents flow parallel to the shoreline.	
(1) work of waves and shore currents	
Waves and shore currents alter shorelines by erosion and deposition.[48]	*What are the effects of waves and currents on shorelines?* (D-53)
(2) classes of shorelines	
Shorelines are classified according to their origin.	
Emerged shorelines formed when the land rises or the water recedes are comparatively straight and are characterized by shallow water, offshore bars, and lagoons.	
Submerged shorelines formed when the land sinks are irregular and are characterized by promontories and bays.	
Neutral shorelines were not formed by emergence or submergence, while compound shorelines show features of both emergence and submergence.	

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[47]Wave height depends upon the wind velocity, the distance over which the wind has been blowing, and the wind duration.

When waves approach shore in shallow water, the lowest point of the wave hits bottom causing the wave to become higher until the top breaks forward forming a "breaker." In deep waters, waves do not break until they strike land. The returning water from waves breaking diagonally across a shoreline forms a longshore current that flows parallel to the shoreline.

[48]Some of the major erosional features of waves and shore currents are sea cliffs, wave-cut terraces, stacks, and sea caves.

Some examples of depositional features are beaches, bars, and spits.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
B Constructional forces	
Forces beneath the earth's crust and at its surface cause movements of the earth's crust.[49]	*What is the difference between a theory and a fact?*
1 earth movements	
There is evidence that the crust has risen and the sea has receded many times in geological history.	
Present changes that can be observed are clues to what may have happened in the past.	
a evidences	
(1) structural features of mountains	
Mountains, with their strongly folded and broken rock, indicate that strong forces have acted in the past.	
Horizontal layering is characteristic of sedimentary rock. Folded, tilted, or fractured sedimentary rock is evidence that forces have acted on the rock.	
(2) earthquakes	
Earthquake zones are generally associated with recently uplifted regions that are bordered by faults.[50]	*Where are most earthquakes occurring?*
(3) volcanoes	
Mountains and islands have been formed or extended as a result of volcanic activity.	*Point out the similarity of earthquake and volcanic zones.*

[49] It is suggested that pupils be given the opportunity to observe the effects of these forces directly, if possible, and to supplement these observations by some of the many excellent pictures or slides of appropriate formations.

[50] Earthquake data cards can be obtained from: Director, National Geophysical Data Center, Environmental Data Services, NOAA, Boulder, Colorado 80302. Have student teams plot data on one wall map of the world using colored pins or felt pens on acetate.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
(4) location of fossils	
Fossils of marine animals and plants are often found in rock high above sea level.	
b possible causes	
(1) theory of isostasy	
Unequal pressures below the earth's crust are created when large amounts of material are removed from the continents and deposited on the ocean bottoms. The deposits cause the ocean floors to sink and the continents to rise.[51]	*How can isostasy be illustrated?* (D-54)
(2) continental drift theory	
Shapes of continents and correlation of rock layers on opposite sides of oceans provided evidence that the continents were once part of one large landmass.[52]	*What is the evidence for continental drift?* (D-55)
Convection cells within the mantle provide energy to cause crustal spreading.[53]	
The movement and interaction of the crustal plates over millions of years helps explain many of the earth's landscape features and the present location of continents.	
c folding and faulting	
Lateral pressures from crustal movements cause folding of rock into upfolds (anticlines) and downfolds (synclines). Under pressure, a fracture may develop along which bedrock is displaced.	*How do rock layers become folded?* (D-56)
d earthquakes	
Vibrations in the earth's crust may occur when the equilibrium of a portion of the earth is disturbed. Earthquakes result from the faulting of rock strata by internal forces.	

[51] Mountain ranges should form near the borders of continents, according to the theory. The fact that mountain ranges do occur as long, linear features bordering the continent makes the theory more acceptable.

[52] Scientists have found sufficient similarity (e.g., age, composition, and thickness) in formations on opposite sides of the Atlantic Ocean to infer that they may be parts of the same formation.

The occurrence of an earthquake (or a large underground explosion) may be detected by a seismograph. Three seismographs at different locations may be used to pinpoint the source.

2 major landforms

Plains, plateaus, and mountains are major landforms developed mainly by constructional forces.

a plains

Plains are broad, flat regions of undisturbed, horizontal rock strata that have little variation in elevation (low relief).

The rock strata of plains may originate from uplifted continental shelves, river deposits (flood plains), glacial deposits, lake floors, or lava flows.

b plateaus

Plateaus have undisturbed, horizontal bedrock with high relief, usually more than a thousand feet.[54]

The elevated bedrock of a plateau may originate from faulting, the slow uplift of bedrock without faulting, or lava flows.

c mountains

Mountains have disturbed or nonhorizontal bedrock. They may originate by movements of bedrock (folded mountains and fault-block mountains) or by vulcanism (dome mountains and volcanic mountains).[55]

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[53] According to the theory of plate tectonics, the earth's crust is divided into a series of rigid plates bounded by ocean ridges, trenches, and active fold belts. The "drifting" of these plates accounts for the change in location of the continents.

[54] Most of New York State is in the Appalachian Plateau. The Catskills are not mountains since the rock strata are mainly horizontal. (See Appendix B, page 70 [4].)

[55] The Adirondack Mountains are domed mountains formed by an igneous intrusion that pushed up the overlying strata.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
C Vulcanism	
Vulcanism is the movement of molten rock at or near the earth's surface.	
Hot, liquid rock, generated within the crust, is called magma; lava is magma on the earth's surface.	
1 extrusive	
In certain localities, molten rock and gases reach the surface in the form of volcanic eruptions and fissure flows. Although lava flows are destructive, the lava weathers rapidly to form very fertile soil.	
The ultimate cause of vulcanism, the process by which magma is generated, is unknown.	
2 intrusive	
Igneous intrusions are the result of volcanic activity which does not reach the earth's surface.[56]	
Most magmas never reach the surface, but solidify to form igneous rocks underground.	
III Age of the Earth	
A The rock record	
The study of the rocks, their composition, their position, and their fossil content gives clues as to how they were formed. Present changes are clues to what may have happened in the past.[57]	*What can be inferred from the study of fossils?* (D-57)

[56]Examples of igneous intrusions are dikes, sills, laccoliths, and batholiths.

The Palisades of the Hudson River are an example of a sill which has been exposed by erosion.

[57]It is important to stress that, except for the last few thousands of years, there is no written, firsthand evidence of geological events. Everything else must be reconstructed using every bit of available evidence. (See Appendix B; pages 78-9 [8], [9].)

The principle of Uniformitarianism or Uniformity of Process is essential to interpreting geologic history. It is assumed that processes observed today occurred similarly in the past.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
1 fossil content	
Fossils are the remains or evidence of animals and plants that lived in the geologic past and were buried in mud, sand, frozen ground, or other material.[58]	*How are fossils formed?* (D-58) *How can fossils be identified?* *(See Appendix B, page 73* [6].)
a occurrence	
Fossils are found almost exclusively in sedimentary rocks and are not found in igneous rocks, and only rarely in metamorphic rocks, because of the great heat and pressure.	
b conditions necessary for preservation	
An organism usually must possess hard parts and be buried immediately in order to become a fossil.	
c interpretation of fossils	
Fossils often indicate the development of life, climates of the past, and the conditions under which they were formed.	
The relative age of sedimentary rocks and the conditions under which they were formed may be interpreted by the fossils they contain.	
Index fossils (fossils of organisms which existed only a short period of time and were relatively abundant) are useful in identifying the relative age of rocks in widely separated areas.	
2 rock sequence	
The relative age of sedimentary strata is usually indicated by their position; the	*What can be inferred about the relative age in a rock sequence?* (D-59)

[58] Fossils may be formed by processes such as petrifaction or leaching. Some fossils are only imprints of the original organism (casts or molds).

oldest rock layer is normally on the bottom, the most recently formed layer on the top. This is commonly referred to as the Law of Superposition.

Intrusions of magma were formed more recently than the rocks they intrude.

3 crustal processes

Evidence of crustal uplifts, followed by long periods of erosion and deposition exist in the rock record.[59]

What can be inferred from the position of rock layers in a sequence? (D-60)

4 radioactive dating

The actual age of most rocks can be determined by radioactive dating.[60]

B The earth's history

1 age of the earth

It is estimated that the earth is about 5 billion years old.

2 the earth's beginning

It is not known how the earth was formed, but numerous hypotheses have been proposed.[61]

a tidal hypotheses

That the earth and other planets were formed when a star passed close to the sun, pulling away gaseous material to form the planets.

b condensation hypotheses

That the sun and the planets formed when a huge rotating mass of gas condensed.

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[59] Almost all of the rocks formed during the first 2 billion years of the age of the earth have been worn away, buried, or greatly altered.

[60] The spontaneous breakdown of the nuclei of the atoms of an element to form a different element proceeds at an exact rate unaffected by changes in temperature, pressure, or other environmental conditions. Knowing the rate of decay and the amount of undecayed substance remaining, it is possible to calculate the age of a rock.

[61] Most fall into two categories: (1) tidal hypotheses and (2) condensation hypotheses. No one hypothesis is completely satisfactory. Continued exploration of the solar system may provide additional evidence.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
3 geologic history	
Geologic time is divided into eras (long periods of deposition). Each era is separated from the subsequent one by shorter intervals of mountain building. The life forms differed for each era because of the major climatic changes between eras. Many species could not survive these changes and died out. New species that were more adaptable evolved.	*What may be inferred from a geologic time scale?* (D-61)
a Pre-Paleozoic time (about 4.5 billion years' duration) Earliest time was characterized by widespread vulcanism, the formation of high mountain ranges, the deposition of ores, the advance and retreat of the oceans, and the beginning of life.[62]	
b Paleozoic era - (about 350 million years' duration) The Paleozoic (ancient life) era was a time of periodic emergence and submergence of the continents.[63]	
c Mesozoic era - (about 155 million years' duration) The Mesozoic (middle life) era was a time of volcanic activity and widespread submergence and uplift during which the reptiles (dinosaurs) predominated. This is also known as the Age of Reptiles.	

[62]There is little fossil evidence preserved from this era. It is thought that simple organisms were dominant.

[63]This is also known as the Age of Invertebrates, Fishes, and Amphibians. Much of our present-day coal, petroleum, and natural gas deposits were formed at this time.

CONCEPTS AND UNDERSTANDINGS	QUESTIONS AND ACTIVITIES
d Cenozoic era - (about 65 million years' duration The Cenozoic (recent life) era is characterized by the uplifting of the mountains in western North America, glacial periods, and the development of mammals. This is also known as the Age of Mammals.	

D-1. Changes in the Earth's Surface [1, 2, 14]

(a) Display and discuss pictures of the easily recognizable changes such as the destruction of features by earthquakes, hurricanes, streams, the emergence or submergence of land along the edges of continents, and the lowering of the water level along portions of the Great Lakes. Good examples of humanmade changes are "before and after" pictures of wooded areas converted to farmland or housing developments.

(b) Take pupils on a fieldtrip of the school grounds. Have them look for evidence of change. Among the changes they may observe are worn staircases, cracks, discolorations and worn spots on the outside of the building, cracks and worn spots on sidewalks and asphalt, rain gullies, and bare spots in lawns.

Pupils can list their observations and then draw inferences about the changes that have occurred. This activity is a good opportunity for pupils to learn to distinguish between observations and inferences.

D-2. Identifying Minerals in Rocks [14, 2, 1]

(a) A demonstration that clearly shows the distinction between a rock and a mineral makes a good introduction to the study of the earth's crust. Select a large specimen of rock in which the minerals are conspicuous such as granite, gneiss, schist, or pegmatite. From the mineral supply, select specimens that are the same as those in the chosen rock. Ask pupils to examine these mineral specimens and try to identify them with each mineral in the rock. The demonstration may be repeated with other rock specimens and minerals.

(b) Crush some coarse-grained rock. (CAUTION: Rocks crushed with a hammer should first be placed in canvas bags to prevent flying splinters.) Provide pupils with a piece of the original rock as well as some of the crushed material. Have them sort the crushed material into piles of similar pieces. Have them describe the rock and each of the piles and relate the piles (minerals) to the original rock. Rock that has been crushed for this purpose is available from a number of commercial suppliers.

D-3. Identification of an Unknown Mineral [22, 14, 5]

Pupils should be provided with an unknown mineral along with the minerals used in activity D-4. It is suggested that the unknown be a different variety of one of the minerals from this list (e.g., smoky quartz vs. milky quartz).

Pupils should conduct the tests described in activities D-4 through D-10 on the unknown and compare the results with the data collected from these activities.

Pupils should be reminded that color is not always reliable. In addition, density results may not be accurate enough for identification purposes.

This is a somewhat challenging activity and may not be appropriate for all pupils.

D-4. Determining the Hardness of Minerals [15, 5, 2]

The relative hardness of minerals can be determined by performing the scratch test with substances to which a hardness number has been assigned or determined. The assigned numbers in Mohs' scale of hardness are:

1 - talc	6 - orthoclase
2 - gypsum	7 - quartz
3 - calcite	8 - topaz
4 - fluorite	9 - corundum
5 - apatite	10 - diamond

In the field, the approximate hardness of minerals is determined by using common materials with approximate hardness numbers as follows: fingernail - 2.5; copper penny - 3.5; knife or steel file - 5.5.

Provide each pupil with a set of minerals such as quartz, orthoclase feldspar, hematite, biotite mica, muscovite mica, calcite, kaolinite, gypsum, galena, and talc. Each pupil should have a steel knife or file and a copper penny.

Have the pupils try scratching all the minerals with the steel knife or file, and list them as either *softer* or *harder* than steel. Some of those that are softer than steel can be scratched with the fingernail or a penny and are, therefore, soft. The minerals may now be grouped under the headings *soft*, *fairly hard*, and *hard*. To find the relative hardness among the minerals themselves, scratch them on each other and arrange in order according to increasing hardness. A mineral is harder than the one it scratches. Minerals of the same hardness do not scratch each other. It is advisable to try to scratch mineral *A* with mineral *B* and then to reverse the procedure. A fresh surface must be used for this test because mineral *B* may leave a mark on mineral *A* which appears to be permanent; however, the mark may be a powdered streak of the softer mineral which can be rubbed off.

Samples of the 10 minerals in Mohs' scale of hardness are often available in the school. Pupils with considerable interest in this topic may wish to use this method to get more exact determinations.

D-5. Determining Cleavage or Fracture of a Mineral [14, 2, 1]

When some minerals break, they split easily along definite planes leaving flat, smooth surfaces in one or more directions; such minerals have *cleavage*. When other minerals break, they leave a rough, splintery, or a smooth, curved (shell-like) surface; this is called *fracture*. Have the pupils indicate which of their specimens in activity D-4 have cleavage and what type. If no cleavage is apparent, have them state the fracture of the minerals as being rough, splintery, or shell-like (conchoidal). Pupils may have difficulty in determining the type of cleavage.

Pupils should be informed that since the specimens have already been broken from larger samples, further breaking is not necessary.

D-6. Determining the Streak of Minerals [14, 5, 2]

Provide each pupil with the minerals from activity D-4. Each pupil should have an unglazed porcelain streak plate. Have pupils test for the streak of these minerals and record their results.

When a colored mineral is powdered, the powder may be a different color from that of the mineral. A mineral may be powdered by rubbing it on a streak plate. Ask pupils to indicate the color of the streak, if any, each mineral makes when rubbed on the streak plate.

After pupils have determined the streak of these minerals, have them test quartz, garnet, and olivine. These hard minerals will scratch the plate and give no identifying streak. Pupils can immediately eliminate very hard minerals when they try to identify any "unknown" that scratches the plate.

D-7. Determining Luster of Minerals [14, 2, 1]

Provide each pupil with samples of the minerals listed in activity D-4. Instruct them to classify the minerals as having metallic or nonmetallic lusters. Have them try to classify the nonmetallic lusters as waxy, glassy, dull, earthy, and so forth. Some leeway should be permitted as distinguishing between some nonmetallic categories is difficult for many pupils.

A simpler classification system would involve only three categories: metallic, nonmetallic shiny, and nonmetallic dull.

D-8. Determining the Color of Minerals [14, 2, 1]

Provide each pupil with samples of the minerals listed in activity D-4. Observe the fresh, untarnished surfaces of the minerals and note the color. Point out that the color of many of the minerals varies widely and that color is not as reliable for identifying minerals as streak.

D-9. Formation of Mineral Crystals [4, 5, 12]

To show how mineral crystals form, dissolve about an ounce of table salt in a half pint of boiling water. Pour the solution into a saucer. Place a string in the solution and over the edge of the dish. Allow the solution to evaporate slowly for a day or two and then note with a hand lens the cubic crystals of salt in the dish and along the string. Repeat this experiment using alum, sugar, or borax. Suspend copper sulfate seed crystals tied to *waxed* thread in a beaker of saturated copper sulfate solution. This will produce some very large crystals within a few weeks.

D-10. Determining the Density of Minerals [4, 5, 12]

(a) To determine the density of a mineral, pupils should first determine its mass using a laboratory balance. The volume can be calculated by placing the mineral sample in a graduated cylinder partially filled with water. The difference between the readings before and after the sample is added is the volume.

The density of the mineral can be calculated using the formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

Pupils should be instructed in the proper use of the balance and graduated cylinder. The samples for activity D-4 should be used for density determinations.

(b) The following procedure may be used either as an alternate or in addition to part (a) if a greater understanding at density is desired. It is more sophisticated since it involves drawing graphs and, therefore, may not be appropriate for all pupils.

Provide pupils with a bucket of marble chips (other substances uniform in composition and insoluble may be used in place of marble). Have pupils pick out about 5 chips (more if they average less than 1 cm in diameter, less if greater than 1 cm) and determine the combined mass and combined volume (see part (a)). The procedure should be repeated using about 10, 15, and 20 chips.

Pupils should graph their volume results on the horizontal axis and mass results on the vertical axis. A straight or nearly straight diagonal line should result indicating that there is a constant relationship between mass and volume. This relationship (density) remains the same regardless of the number of chips used.

To verify that the density is constant for a uniform substance, pupils can calculate the density for the four trials using the formula in (a).

D-11. Testing for Carbonate [6, 2, 1]

The teacher may wish to demonstrate the carbonate test by applying a drop of dilute hydrochloric acid to each specimen and note any effervescing or bubbling. Ordinary household vinegar may be used in place of the hydrochloric acid. Of all the specimens mentioned in activity D-4, the only carbonate is calcite. Note: When preparing acid for laboratory use, use one part of concentrated hydrochloric acid to nine parts of water.

D-12. Crystallization of Minerals From A Melt

Crystallization of minerals from a melt can be demonstrated by placing a small quantity of salol* on a watch glass. The watch glass is placed on a beaker of water which is heated by a bunsen burner. Once the salol has melted, the burner is removed and the salol allowed to cool.

The cooling process can be speeded up by carefully removing the watch glass with forceps from the top of the beaker and placing it on the table. (See also activity D-16.) Safety Note: Pupils should be cautioned to exercise care in the handling of hot materials. Pupils should be instructed in the proper use of a bunsen burner.

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* Salol = Phenyl Salicylate - a white, crystalline substance, prepared by treating a mixture of sodium salicylate and sodium phenoxide with phosphoryl chloride.

D-13. Deposition of Minerals by Evaporation [2, 1, 14]

Prepare a saturated solution of table salt in water. Place in an evaporating dish and allow to stand uncovered overnight. Observe the crystals of salt in the bottom of the dish. The action may be speeded up by heating the dish to evaporate the water.

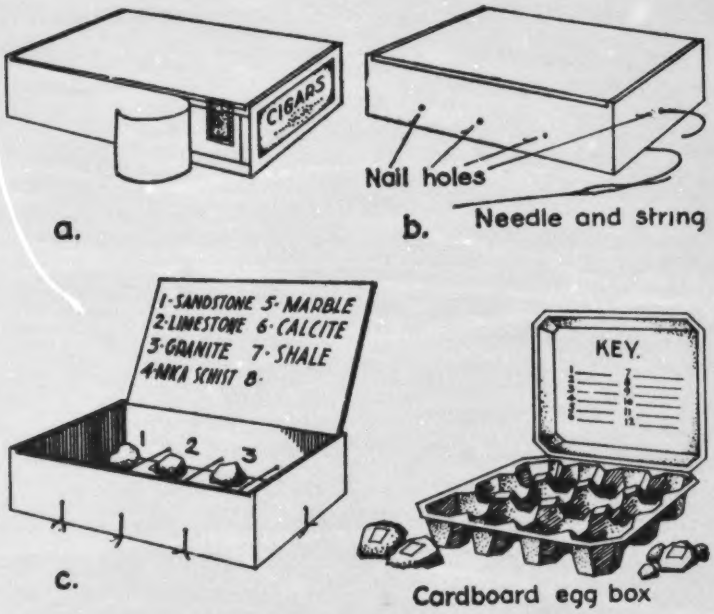
D-14. The Use and Conservation of Natural Resources [22, 15, 14]

Have pupils individually or in small groups select one natural resource for study. They can research the extent of the supply; the current amount of usage; the types of usage; projections for how long the supply can last; the amount of the resource, if any, that is imported or exported; other resources, if any, that can be used as alternates; and any conservation measures or wasted usage.

As an option pupils may be encouraged to make recommendations based on their findings. A report of the findings and recommendations, if any, can be submitted as a written report or presented orally to the class.

D-15. Collecting and Describing Rocks [14, 1, 2]

After pupils have studied the different rock types and how they formed, the teacher may wish to encourage interested pupils to pursue the topic further. The following are some activities that can be performed.



Refer to Appendix B, pages 74-7 [7] for additional information.

(a) Encourage pupils to start small rock collections of their own. A neat box for storing a small collection can be made by pasting paper over a cigar box and stringing cords across the inside of the box to divide it into eight or more sections. With a nail and hammer punch evenly spaced holes in the box a short distance from the bottom. Run strings through the holes and around the bottom of the box and tie them tightly on the outside. The strings will then hold the specimens in position.

Cut small squares of adhesive tape and paste one square on each of the specimens collected. Number each specimen. Next, make a key with spaces for the name of each rock. Write in the names of any rocks that are known and paste the key on the cover of the box. Blank spaces can be filled in later if and when the names of the rocks are learned.

For beginners it is well to keep the collections small and to confine them largely to local rocks. Pupils who have a special interest will of course learn how to use more elaborate techniques.

(b) Egg boxes of the pressed cardboard type are convenient for small rock collections. Keys showing the position of each rock can be pasted on the covers.

(c) Break open several rock specimens and compare the appearance of the freshly broken surfaces with the weathered outside surfaces.

To break a rock safely, wrap it in a single layer of cloth. Pull the cloth tightly around the rock and hold it firmly on one side. Place the rock to be broken on a larger rock and strike it firmly with a hammer. The cloth will prevent small chips of rock from flying off through the air.

D-16. Formation of Igneous Rocks [21, 2, 1]

The variation in grain size in igneous rocks can be demonstrated using the procedure described in activity D-12. For the first trial, allow the salol to cool while the watch glass remains on the beaker. For the second trial, remove the watch glass with forceps and carefully place it on some ice cubes in a dish. In the first trial the salol will cool slowly and form large crystals. The second trial should produce small crystals from rapid cooling.

The results should be related to the rapid and slow cooling of molten rock at the earth's surface and deep below, respectively. Pupils can then be given fine- and coarse-grained igneous rocks and asked to indicate how they cooled and where they may have been formed.

D-17. Identifying Some Common Igneous Rocks [14, 2, 1]

Provide each pupil with a hand lens and a collection of the following igneous rocks: granite, gabbro, basalt, pumice, and obsidian. Help pupils to arrange the rocks on their desks in a definite order such as given above. Pupils should note that these igneous rocks are generally light-colored or dark-colored. Point out that the light-colored rocks are composed largely of the light-colored minerals, quartz and orthoclase feldspar, while the dark-colored rocks are composed largely of the dark-colored minerals pyroxene and olivine. Ask pupils to separate their igneous rocks on a basis of light and dark color.

Ask pupils to hold the specimen of obsidian so that light will pass through a thin edge. The true color of obsidian is colorless or light-colored rather than dark because its composition is chiefly the same as that of granite. The dark color is due to impurities, such as tiny particles of magnetite, which absorb the light. The rock can be compared to artificial glass, which also is colored by small amounts of impurities. The effect of impurities can be demonstrated by adding a small quantity of dye to a beaker of water and noting the effect on the color of the water.

Based on their observations, pupils can classify the rocks using a chart such as the one in the appendix. The chart also indicates the minerals present in each rock.

Using the hand lens, pupils may be able to recognize some of the minerals in coarse-grained igneous rocks such as granite and gabbro.

Pupils should also describe how (rapid or slow cooling) and where (at the surface or deep below) each rock formed. If pumice is used, some help may be needed as it may appear to be coarse-grained.

D-18. Making Artificial Sedimentary Rocks [6, 1]

This demonstration should not be repeated if pupils have seen it in previous years.

(a) To demonstrate how rock materials are bound together, make an artificial sandstone as follows: (1) Fill a large test tube about half full of sand. (2) Add about one-eighth cup of a saturated solution of table salt. (3) Shake the test tube until the contents are thoroughly mixed. (4) After the sand settles pour off the excess water. (5) Allow the mixture to dry and then carefully break the test tube and remove the artificial sandstone. CAUTION: Before breaking the test tube wrap it in a paper bag or sheet of newspaper in order to avoid flying glass. Explain that nature makes natural cements that bind various types of sediments into rocks.

(b) Repeat the procedure described in (a) using a solution of Portland cement or plaster of paris instead of salt as the cementing material.

(c) Show also that a cemented mixture of small pebbles and sand forms concrete, and explain that, when nature cements these same materials together with a natural cement, a rock resembling concrete is formed, known as conglomerate.

(d) Refer to activity D-13 for a description of how sedimentary rocks form by evaporation.

D-19. Identifying Some Common Sedimentary Rocks [14, 2, 1]

Provide each pupil with a collection of the following sedimentary rocks: shale, sandstone, conglomerate, limestone, and dolomite. Several varieties of limestone may be used: compact, fossiliferous, coquina, chalk, and coral. Each pupil should also have a hand lens. Help them to arrange their rock specimens in a definite order.

(a) Have pupils describe the size of the particles in each specimen (pebbles, sand, silt, clay, or crystalline). Distinguishing between sand and silt or silt and clay may be difficult. The teacher may wish to eliminate the silt category to simplify classification.

(b) The teacher should apply a drop or two of dilute hydrochloric acid to each specimen and note any bubbling or effervescing. Replace applicator *immediately* after use to avoid spilling the acid. Rocks that effervesce contain carbonate. Those that do not may be classified as non-carbonates (usually they are silicates).

(c) Using the chart in Appendix B (pages 71-2 [5]) pupils can attempt to identify the rock samples.

(d) Once the samples have been identified pupils should describe how each formed. Essentially, this is a distinction between the method of formation of land- and marine-derived sedimentary rocks. (Refer to Appendix B, page 70 [3].)

D-20. Identifying Some Common Metamorphic Rocks [14, 2, 1]

Provide each pupil with a collection of the following metamorphic rocks: slate, marble, quartzite, gneiss, and schist.

Assist pupils in arranging their rock specimens in some definite order.

(a) Ask pupils to examine each rock with a hand lens and try to determine the composition of those in which the minerals or other particles can be seen.

(b) The teacher should apply a drop or two of dilute hydrochloric acid to each specimen and note which ones show a bubbling effect. Replace the applicator *immediately*.

(c) Have pupils pick out those rocks in which the minerals appear in more or less parallel bands (gneiss, schist, slate). If the minerals are coarsely banded, the rock is called gneiss; if finely banded, the rock is called schist. The tiny flakes of mica in slate are too small to be seen, but they give the rock its banded effect and ability to split (slaty cleavage). The other rocks (marble, quartzite, anthracite coal) are massive or show no banding because they are composed of a single mineral, or plant remains in the case of anthracite. The pupils should now be able to determine:

- Which specimen resembles granite
- How the arrangement of the minerals in this rock differs from those in granite
- Which specimens, other than gneiss, show a foliated (banded) structure
- Why the other specimens do not show a foliated or banded structure and an explanation of why not.
- Which specimen was changed from limestone

- How this rock differs from the limestone other than in color
- Why some marbles are streaked with colors while others are not

D-21. Studying the Ocean [11, 12, 14]

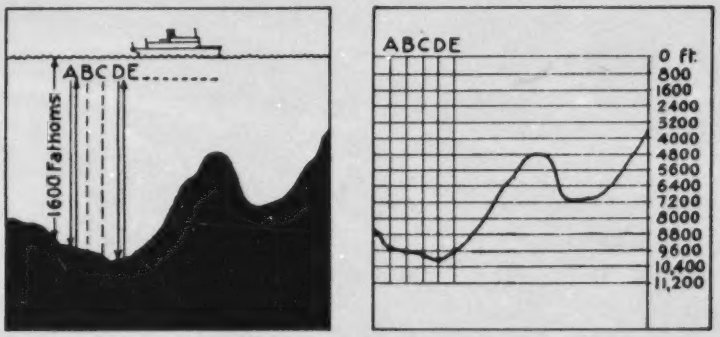
It is difficult and time-consuming to devise demonstrations and experiments illustrating means of studying the ocean. Most of the devices are based on physical and chemical principles, some of which the pupils may not know. If the devices are discussed in relation to principles, they probably should also be discussed as applications when the principles are discussed.

Devices are subject to change depending on scientific advances. Pupils may be asked to discuss or speculate how the following information may be obtained.

- Depth of ocean and shape of the floor (sonic devices based on the principle of reflection of sound)
- Thickness and depth of sediments (devices similar to the above but also based on refraction of sound waves due to different speeds in different media - similar to seismographs)
- Composition of sediments (direct observation of cores including chemical and spectroscopic analysis)
- Presence and speed of currents (floating device with some means to determine its location)
- Direct observation (underwater devices using compressed air)

D-22. The Shape of the Ocean Floor [12, 14]

Pupils may tend to visualize the ocean floor as being completely flat. It can be pointed out that the islands in the oceans are essentially the tops of mountains or mountain ranges that extend above sea level.



a b

The distance to the floor of the ocean or to any object under water may be measured by sonar equipment which operates on the same principle as radar. This device has been used to plot the contours of the ocean floor and to assist in the navigation of submarines under ice by locating the bottom of the ice sheet above the submarine. Sonic or supersonic waves are transmitted through water in a known direction. The waves are reflected from a surface or object and return to the receiver in a measured time. The location of the object is automatically computed based simply upon the speed of the waves in water and the angle at which the reflected waves return to the vessel.

In the diagram, assume that a wave is transmitted vertically downward from *A* position, reflected and returns in 4 seconds. The velocity of sound in water varies with the temperature and concentration of minerals, but is approximately 4,800 feet per second. The distance traveled *(s)* is $v \times t$, or 4,800 ft./sec. $\times$ 4 sec. = 19,200 feet. The distance to the obstruction (possibly the ocean floor) is 9,600 feet or 1,600 fathoms (1 fathom = 6 feet).

The results of the soundings are then plotted as shown in diagram (b).

D-23. Composition of Sea Water [14, 12]

Accurate determinations of the composition of sea water are beyond the scope of this course. It can, however, be demonstrated that there is more dissolved material in sea water than in tap water.

Two clean beakers should be filled with equal amounts of tap water and sea water. (Note: "Artificial" sea water can be made if necessary by adding 4 grams of salt to 96 grams of water.) The beakers should be allowed to stand undisturbed until all the water has evaporated. Visual inspection should be sufficient to convince pupils that there is more dissolved material in sea water.

Evaporation can be speeded up by heating the beakers.

D-24. Mineral Resources of the Ocean

The teacher may wish to have pupils investigate, using the library, some of the mineral resources of the oceans. A report might include: the types of resources and their extent; their current usage (if any); any projections for future use; how they are or might be extracted from the oceans; and, what research (if any) is currently underway.

D-25. Types of Topographic Maps [1, 2]

Display and discuss the advantages of the various types of topographic maps including:

- A colored relief map (a physical map with relief indicated by a color code)
- A United States Geologic Survey topographical map with relief indicated by contour lines

- A raised plastic relief map showing contour lines or political divisions (greatly exaggerated height scale). Note that this is not strictly a topographic map in that it is three-dimensional.

D-26. Some Uses of Topographic Maps [7, 14, 1]

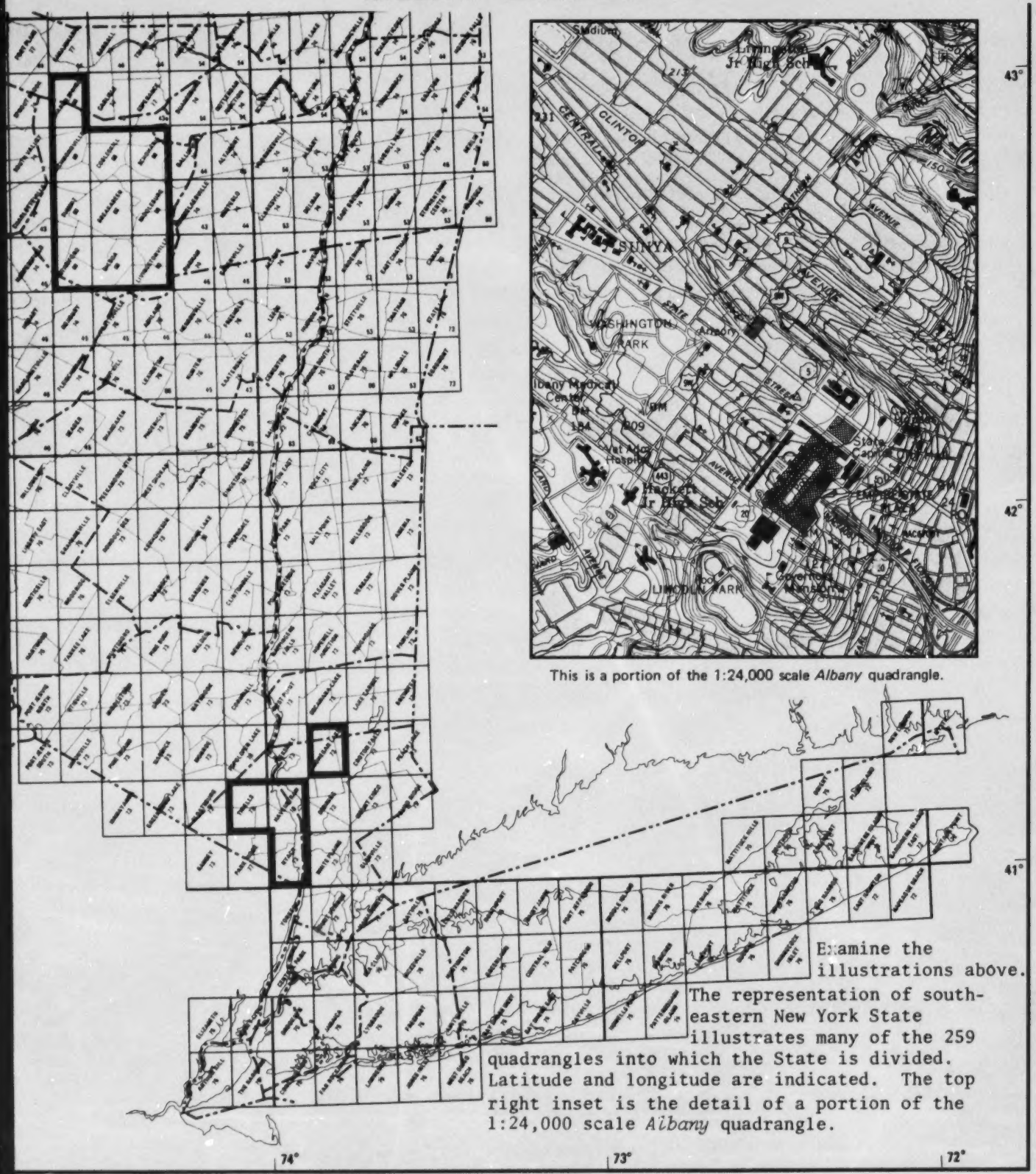
Teachers should give pupils some practice in the use of topographic maps. However, the depth of treatment depends upon the time available, the abilities of the pupils, and whether or not the material has been presented elsewhere. Contours are not presented at this point. Remind pupils that learning to "read" a topographic map is necessary before landscape interpretations can be made. Pupils should not be expected to memorize a large number of symbols. Consideration should be given to permitting pupils to use a code of symbols at all times.

Provide each pupil or a small group of pupils with a topographic map, possibly of the local area. Have them determine some of the following as applicable.

- Name of the quadrangle
- Which quadrangle(s) give(s) additional information beyond the map in a given direction
- The series of the map (7.5 minutes or 15 minutes)
- The latitude and longitude of any point to the nearest minute
- The airline distance between any two points
- The ground distance between any two points along a road or stream
- The area represented to the nearest square mile
- The location and altitude of any bench mark (B.M.)
- The location of any schools, churches, or swamps
- Location and colors indicating major roads, water features, wooded area, and works of man
- Magnetic declination (optional)
- Compass direction from one point to another (optional)

D-27. Learning About Quadrangles [14, 2]

New York State has been divided into 259 separately named quadrangles. Obtain a free *Index Map for New York* from the Chief of Distribution, United States Geological Survey, Washington 25, D.C. This will give the name of the quadrangle in which the school is located. Then order from the Geological Survey a copy of the quadrangle for each pupil. When ordering, request a free pamphlet, *Topographic Maps*, which describes map symbols and explains how the maps are made.



CLINTON
SUNYA
WASHINGTON PARK
LINCOLN PARK
Governor's Mansion
Albany Medical Center
Vet Admin Hospital
Hackett Jr High Sch
State Capitol
787
90
90
787
787
787

D-28. Topographic Concept [14, 15, 1]

The following simple demonstration will introduce the concept of contour maps in a simple and clear manner.

a b

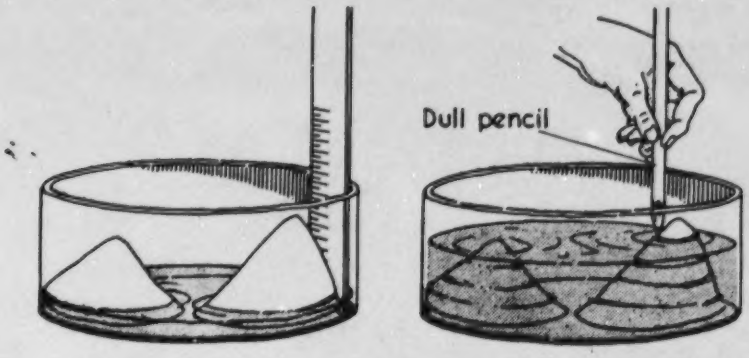
- Rule parallel scratches one-sixteenth of an inch apart in the surface of a 2-inch by 2-inch glass slide that has been opaqued (see diagram). Clear glass can be opaqued satisfactorily with a thin coat of black tempera paint. The slide in the illustration is an emulsion-coated lantern slide.
- Hold the ruled slide up to the light to make sure that all lines have cut through the opaque coating.
- Place the slide with lines horizontal in an ordinary 2-inch by 2-inch projector and focus on any surface made to simulate irregular terrain.
- Note how the projected "contours" follow each irregularity in the surface of the cloth mountain (see diagram). When viewed from directly overhead, the lines form a contour map.
- Projected from the correct angle, the lines will contour any surface. Experiment until the desired effect is obtained.

D-29. Teaching Contour Maps With Clay Models [22, 15, 12]

To serve as a substitute in areas where activity D-30 is impractical, the teacher may resort to the use of clay models.

In a shallow vessel such as a bell jar, refrigerator pan, or candy tin, build a miniature landmass from about a pound of modeling clay. One portion of each hill should touch the sides of the vessel, as shown in the diagram. Shape the clay so there are two hills of unequal height; part of the slope of the lower hill should butt up against the side of the vessel.

Stand a ruler in the vessel and pour water into it until the 1-cm mark is reached. With a dull pencil, scribe a line around the hills at the waterline. Pour in more water until it rises another 1-cm and mark another contour line. Continue until the contours reach the top of the model. Pour out the water and an excellent contour model results.



Viewed from directly overhead, this model exhibits a feature of contour maps also brought out by activity D-30; namely, if a slope is completely within a mapped area the contours are closed lines. Where a slope extends beyond the edges of a topographic map, the contour lines end at the map's edges.

Fasten a clear plastic sheet to the top of the vessel and, looking directly down into the vessel, trace the contour lines onto the plastic sheet. If the plastic sheet is thin, it may be necessary to place a transparent cover or rigid plastic over the vessel first. Pupils should relate the plastic sheet "topographic map" to the original model.

D-30. Measuring Contours [22, 15, 12, 6]

Fieldwork on the schoolground or any nearby area that is not flat is an effective way to advance the study of topographic maps. With easily made and inexpensive materials, pupils will grasp quickly the concepts of the contour line, contour interval, and features which give topographic maps much of their uniqueness.

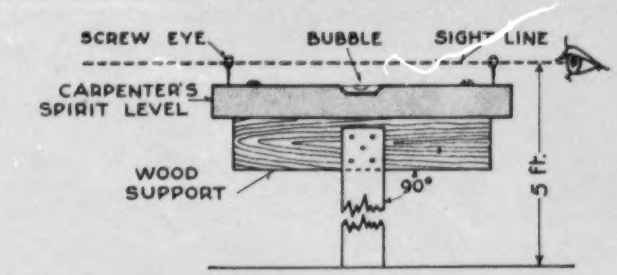
At a lumberyard obtain 15 or 20 strips of scrap trim at least 8 feet long and approximately 1 by 1/2 inch in cross section. Make a "transit" by fastening, at right angles, a cheap carpenter's spirit level to the top of a 5-foot strip. Add two screw eyes to insure accurate sighting. It is recommended that screws be used rather than nails. If the distance from the top of the spirit level to the other end of the strip of wood is greater than 5 feet, saw off the excess (see diagram *a*).

Select a piece of scrap 8 or 9 feet long and mark it off into 1-foot sections with dark, broad lines. Beginning at the bottom, number the lines from 1 through 8. This will be a "rod."

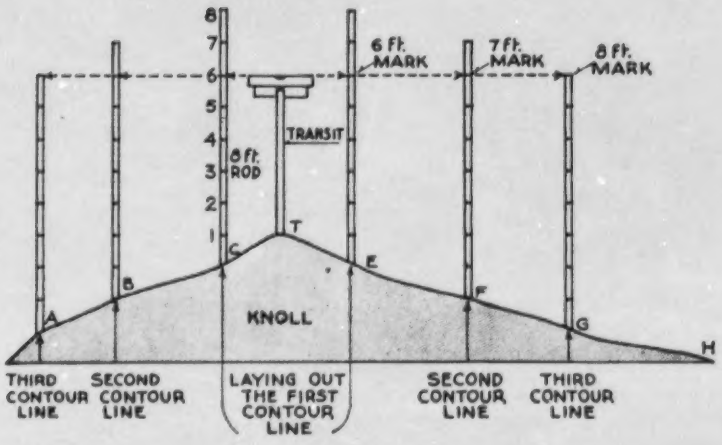
Cut some of the scrap into 20 or more 1-foot lengths for stakes. In actual use, you will need one transit, one rod, one hammer, and six or seven stakes for each group of four pupils.

Choose an irregularly sloping plot 50 to 100 feet on each side for the study area. At the highest point of the plot, set the transit on the ground in such

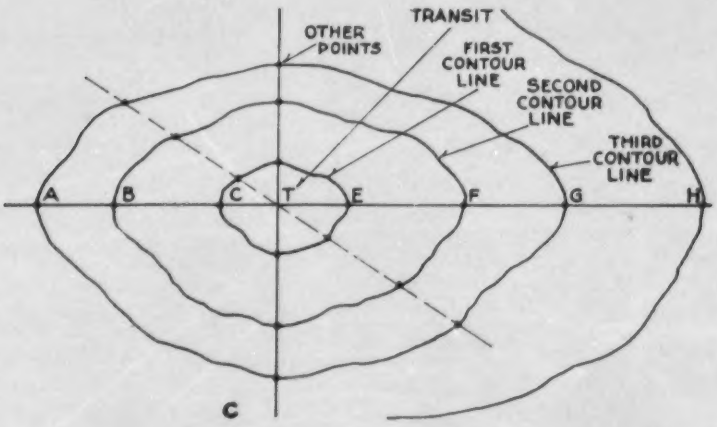
a way that the level indicates the transit is exactly vertical. A rod bearer then moves a few feet down the slope, stands his rod on the ground, and permits the transit user to sight on the 6-foot mark of the rod. Actually, two pupils operate the transit; one holds it constantly vertical while the sighter can only rotate it. The sighter tells the rod bearer where to move the rod in order that he can sight through the screw eyes on the 6-foot mark on the rod.



a



b



c

A sight obtained, the fourth pupil drives a stake into the ground at that spot, and he and the rod bearer move a few feet in another direction from the transit pupils in order to establish another point on this contour line which is 1 foot (vertical) below the base of the transit. Time and space permitting, it is desirable to have many points along each contour (see diagram *b*).

To establish these preliminary points on the first of the series of contour lines involves only four pupils. However, the other pupils will need to watch attentively so that they will be able to participate in determining other points on different lines.

After the first contour line has been established, proceed to lay out the second contour line. To obtain this next contour line, direct a rod bearer to go down the slope far enough so the transit sighter can line up on the 7-foot mark on the rod. Similarly, to obtain the third contour line sight on the 8-foot mark on the rod, and so on. In order to obtain additional (lower) contour lines, it will be necessary for the transit bearer to move down the slope to a point which has already been determined and indicated by a stake. See diagram *c* for a view from directly above the first position of the transit.

As pupils lay out these contour lines they will grasp their meaning with little teacher explanation. If a separate length of twine is fastened to each stake on any given contour, fundamental relationships will become still more apparent. The class should gain these understandings:

- All points along a contour line have the same elevation.
- The contour interval is the vertical distance between contour lines.
- Contours never cross or divide.
- Contours are evenly spaced only where the slope is uniform; generally, spacing is uneven.
- Where the slope is steep, contour lines are close; they are far apart on a gentle slope.
- Where a contour line crosses a stream, gully, or depression, the lines appear to go upstream or uphill respectively.

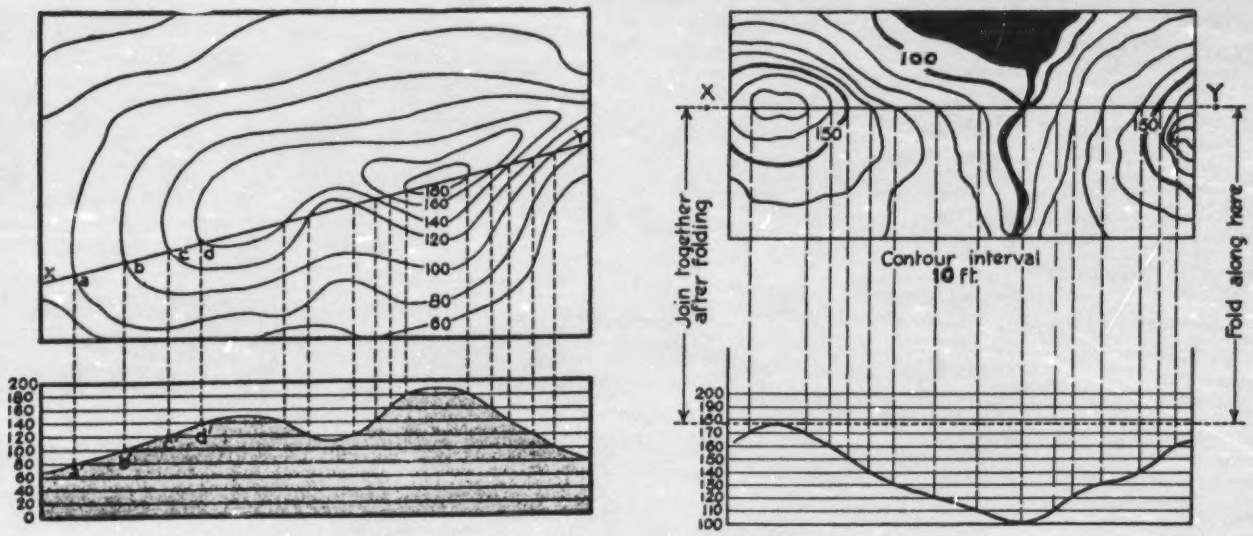
D-31. Topographic Profiles [22, 15, 12]

In order to obtain a better understanding of the nature of the topography, topographic profiles can be constructed. These are lines which show the rise and fall of the land surface along a selected line crossing a portion of a map.

(a) Refer to diagram *a* on the following page and trace through the following steps.

- Draw line *XY* across the map at the desired location.
- Place a piece of horizontally-ruled paper so that its top edge lies along line *XY* (or it may be placed along the bottom edge of the map). Each horizontal line represents a contour interval and is so numbered along the left-hand edge.
- Starting at the left, drop a perpendicular from point *a* where the 80-foot contour intersects *XY*, down to the corresponding horizontal level.
- Mark point *a* on the horizontal line.
- Repeat the procedure for the 100-foot contour at *b*, and so on until all points have been plotted.
- Draw a smooth line through all the points, thus completing the profile.

(b) A more vivid "3-D picture" effect may be produced by the pupils in the following manner. Prepare a dittomaster of a contour map and scale as shown in diagram *b*. Provide all pupils with copies and have them construct the profile along line *XY* as described in (a) above.



a *b*

D-32. The Weathering of Rock [14, 5, 4]

The following activities permit pupils to observe the effects of the weathering of rock.

(a) Find evidences of rock weathering near the school. Compare the rock surfaces of new and old stone buildings. If a cemetery is convenient to visit, it will be interesting to compare the dates on the stones with the degree of weathering and also to note the effect of weathering on different kinds of rock. A short fieldtrip might be planned to help develop these understandings, once permission has been obtained from landowners.

(b) Place some small, freshly-broken pieces of rock in a jar half-filled with clear water. Close the lid of the jar and have several pupils each shake the jar 100 times. Note the appearance of the water after the jar has been shaken at least 1,000 times.

Remove the rocks and allow the sediment to settle to the bottom or filter it out through a paper towel or filter paper.

Compare the rocks that have been shaken in water with freshly-broken pieces. Note that the sharp edges have been rounded and worn away. (NOTE: Softer rocks such as limestone and shale will show greater effects than harder rocks such as marble and granite. It is suggested that a plastic rather than a glass jar be used for greater safety.)

(c) As an option it may be desirable for some pupils to investigate the difference in weathering rates for different rocks. This can be accomplished by repeating procedure (b) using a rock of greater hardness. In addition, it will be necessary for pupils to measure the mass of the rock chips before and after shaking.

If this activity is to be performed, the rock chips should be soaked in water overnight. If not, pupils will often find a gain in mass after shaking because the rocks have absorbed water.

D-33. The Composition of Soil [14, 2, 1]

Allow each pupil to study a pinch of soil with a hand lens. The most common materials will probably be sand, clay, and organic matter.

Dig a hole about 20 cm deep in an area covered with vegetation. Have pupils compare a sample taken from near the surface with one from a depth of 20 cm. The composition will be similar except for the presence of organic matter in the surface sample. (NOTE: The thickness of the topsoil layer varies from place to place. In some locations it may be necessary to dig deeper than 20 cm.)

If there is an exposed road cut or excavation site in the area, it may be possible to observe the sequence of soil formation from bedrock to subsoil to topsoil.

D-34. The Physical Weathering of Rock [14, 4, 6]

The following activities can be used to illustrate physical weathering processes:

(a) Completely fill a screwcap jar with water and tighten the cover. Wrap the jar in a piece of cloth or put it into a paper bag and allow it to freeze

outdoors or put it in the freezing compartment of a refrigerator. The freezing water will expand and break the jar. Absorbed water often breaks rocks in a similar way.

(b) Carefully weigh a piece of dry porous rock such as sandstone or limestone. After soaking in water overnight, reweigh the sample. Discuss what might happen if the water were to freeze.

(c) Examine the sidewalks and highways near the school and notice the spaces between the sections. This is done to prevent breakage when the sections expand.

(d) Heat the end of a piece of glass tubing in a flame and plunge it quickly into cold water. (NOTE: It is strongly recommended that this be done as a teacher demonstration.) Many rocks will fracture in a similar way when heated by the sun and suddenly cooled by rain or a rapid drop in temperature. Avoid heating samples of rock because of the danger of explosion which may result from the conversion of absorbed water into steam. If rock samples are used, it should be a teacher demonstration only and special care should be taken to prevent the splattering of rock fragments.

D-35. The Chemical Weathering of Rock [14, 2, 1]

The chemical weathering of rock can be demonstrated in a variety of ways such as:

(a) Allow pupils to examine two tin cans, one of which is rusted. The rusted one will be much more brittle. This can be related to the oxidation of some rock minerals.

(b) Place a soft stone such as sandstone or limestone under a dripping faucet. Observe the effects of the dripping water on the stone after a few days.

(c) Pupils are acquainted with the test for carbon dioxide in which lime water turns milky (forms a white precipitate) when carbon dioxide is blown into or otherwise mixed with the lime water.

Repeat the demonstration until the white precipitate ($CaCO_3$ or limestone) forms. Continue introducing carbon dioxide until the precipitate disappears. The additional CO_2 dissolves in the water to produce carbonic acid which reacts with the limestone to produce a soluble calcium bicarbonate.

(d) As an alternate to (c) it is possible, using limestone or marble, to demonstrate the result of weathering by the action of an acid. A convenient way to do this is to place the sample in a jar of very dilute hydrochloric acid. Observe the sample the next day and compare it with a similar piece of limestone that has not been immersed in acid.

(e) Fill two similar bottles with water. Cut a notch in each of two corks to fit the bottles. Place the stem of a seedling in one notch and insert the cork into a bottle so that the roots are in the water. Pack cotton around the stem to keep out the air. Plug the other bottle with the second cork and some cotton, but no plant. After a few days test the water in each bottle with brom thymol blue for evidence that roots excrete acids.

D-36. The Biological Weathering of Rock [14, 1, 2]

(a) Look for places where natural or artificial rocks have been broken by the roots of plants. Sidewalks are sometimes cracked and pushed out of place by the roots of trees.

(b) Make a 3-cm thick slab of plaster of Paris (see D-58) either in a vaseline, straight-sided baking pan or by pouring the plaster into a wooden frame resting on a pane of glass. After the plaster has hardened, remove it from the mold.

Lay sprouted pea or bean seeds on the smooth side of the plaster and cover them with wet paper towels. Keep the slab in a terrarium so that the toweling stays moist. After several days remove the seeds and notice what has happened to the surface of the plaster.

Find rocks or rock ledges where mosses and lichens are growing. Scrape some of the plants off and notice that bits of rock flake off, loosened by the chemical action of the plants. A short fieldtrip to see such a rock is an interesting learning activity.

D-37. The Formation of Soil [19, 8, 1]

(a) Place one of the larger flat pieces of rock from the classroom collection on a piece of newspaper and rub a smaller rock over it. Continue rubbing until some rock dust is worn from the rocks. Examine the dust and compare it with samples of soil.

(b) The activities of animals, the action of freezing and thawing, the force of gravity, the work of streams, and many other factors are continually rubbing rocks together and wearing them away. With the aid of plants, the dust that is worn from the rocks may eventually become good soil.

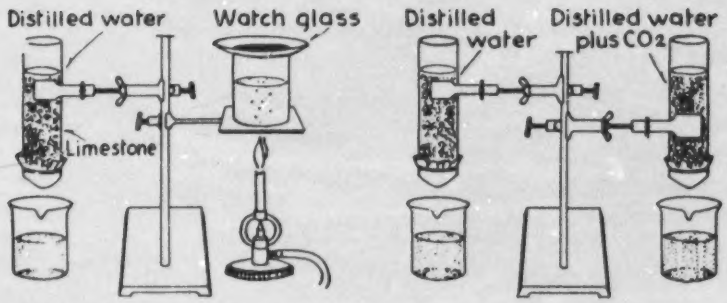
Call attention to the long period of time needed to form good soil and the need for conserving it. Grass fires, forest fires, and wasteful farming practices remove the cover of vegetation from the soil. Discuss various means of preventing erosion and conserving the soil.

(c) If activity D-32 is performed, then the observations made can be used to draw inferences about the process of soil formation.

D-38. Groundwater Erosion of Limestone [16, 14, 1]

(a) To show that acid groundwater dissolves limestone, fill a lamp chimney or large glass tube with crushed limestone or bluestone. Close the bottom of the lamp chimney or large glass tube by tying a piece of cloth across it.

Pour slightly acid water (representing rain water) into the chimney and collect it as it comes off at the bottom. Evaporate a few drops of this water on a glass plate. Use distilled water as a control.



(b) Prepare two chimneys of limestone as described in (a). Into one pour distilled water or rainwater that has been boiled to expel gases. Into the other pour rainwater that has had carbon dioxide bubbled through it. Evaporate water from each chimney and compare the sediment remaining. There should be a larger amount of sediment in the water that contained CO_2. This is good evidence that carbon dioxide helps to dissolve limestone.

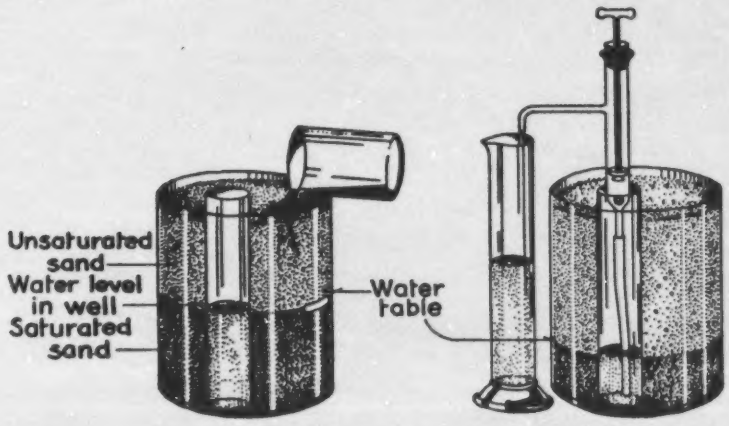
D-39. Minerals in Ground Water [14, 6, 1]

Thoroughly wash two beakers and rinse with distilled water. Place a small amount of water from a spring or well in one beaker. Place an equal amount of rainwater in the other beaker. Set each beaker on a tripod or ringstand and heat with a bunsen burner. When the water in each beaker has evaporated, note the residue of mineral deposits in the beaker which contained spring or well water. Relate to deposits inside tea kettles.

D-40. The Water Table [22, 17, 14]

The following are activities that can be used to illustrate the water table and its characteristics:

(a) A simple model that can be set up within a few seconds presents an excellent approach to the development of the concept of the water table.

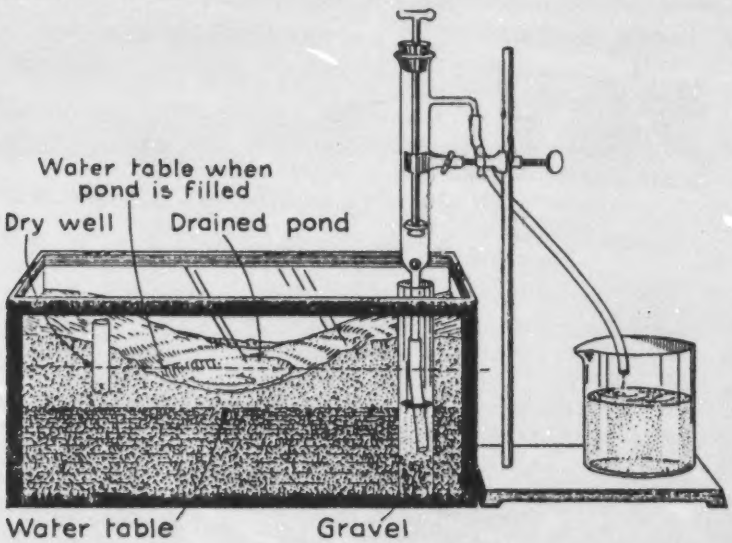


Hold a large-bore glass tube against the inside of a battery jar to represent a well. Fill the jar with sand and pour water on the sand until the water level rises about halfway in the jar. Note that the water level is the same outside the well as it is inside the well. Paste a narrow strip of wet paper on the jar to mark the water level and discuss the term water table.

Use a demonstration lift pump to remove some of the water from the well and call attention to the lowering of the water table.

(b) The effect of lowering the water table can be effectively illustrated by using a demonstration pump and an aquarium filled with sand and water as shown in the diagram. The well and the pond go dry as water is pumped from the glass tube into the beaker. An empty plastic toothpaste tube pressed against the side of the aquarium can be used as the well casing in place of a glass tube.

When the well and the pond have been drained, the water table can be raised again by reversing the position of the pump. A short piece of rubber tubing can be attached to the spout of the pump so that water can be pumped from the beaker back into the well.



(c) It will be obvious to pupils that the source of soil water is rainfall. The height of the water table therefore depends to a large extent upon how effectively water penetrates the soil. A large amount of runoff occurs where soils are relatively impervious to water. Most of this runoff water is carried away by streams and does not help raise the water table.

The relative water permeability of soils of different kinds can be demonstrated very easily with a metal can with both the top and bottom removed, a watch, and a pail of water.

The metal can should be one that has been opened at both ends with a rotary can opener so that the rims are smooth. Press the can into the ground to a distance of about two cm and fill it completely with water. Use a watch

to determine the time required for all the water to go into the soil. Repeat the procedure in different places such as the playground, the lawn, and a cultivated area. The data obtained may be summarized in tabular form.

(d) Ask pupils to tell of places in the vicinity of the school where there is evidence that the water table is near the surface. Swampy or marshy locations, even though they are small in area, can usually be found at a distance that is not too far for a short fieldtrip.

In conducting a fieldtrip of this kind, one of the significant observations that can be made is the difference in the vegetation as compared to adjacent, drier areas. Some of the plants, such as cattails, marsh marigold, pussy willows, and various swamp grasses, which grow only in wet locations, can be identified by their common names. If the fieldtrip is taken in early spring, it will often be possible to find the water table by digging a small hole with a shovel. Attention should be called to the fact that the water table is usually nearer the surface in spring than at other times of the year.

(e) The importance of reducing the amount of runoff water in maintaining a high water table can be shown by comparing an area protected by vegetation and one that is not so protected. The protected area will be much moister than the unprotected area. Water from previous rains will still be helping to maintain the water table in the protected area. The unprotected area will be depleting the water table. Suitable areas for comparison can often be located on or near the school camps or in a nearby park.

The effects of gullying, unwise farming practices, the building of dams and reservoirs, and the construction of drainage ditches can also be related to the water table. The question of whether or not the local community has a water table problem and, if so, what might be done about it should also be considered.

D-41. The Permeability and Water Retention of Rocks [16, 13, 6]

(a) To demonstrate the permeability of some common rocks, place five drops of water on pieces of granite, sandstone, and shale. Observe the rate at which the water penetrates, and note that very little of the water disappears into the shale or granite.

Variations in the permeability of loose material can be observed by filling plastic columns with gravel, sand, and soil respectively. Water is then poured into the top of each tube and timed as it flows to the bottom.

(b) Rocks vary greatly in ability to hold water. Separately record the weight in grams of pieces of granite, sandstone, and limestone. Immerse the rocks in water overnight. Wipe off the excess water and reweigh them during the next class period. Sandstone will have gained the most weight per gram of original weight.

D-42. Field Study of Stream Erosion [17, 14, 3]

(a) After a heavy rain, have the pupils look around the school grounds for evidences of erosion. No matter how gradual the slope is, running water

from a downpour will wash away soil, causing miniature gullies, valleys, deltas, and alluvial fans. Where bare soil comes in contact with the school building, walls, or trees, there will be evidence of splash erosion.

(b) Find a bare slope containing gullies a few centimeters wide where running water has carried away part of the soil. These can frequently be found around new buildings and new road construction.

Calculate the approximate volume of soil removed from one of the gullies. Most gullies are not square in cross section. However, a fair approximation of the cross-sectional area may be obtained by multiplying two-thirds of the width by the depth. This product should then be multiplied by the length of the gully to find the approximate volume of soil lost.

After a rainstorm, make similar measurements of the same little gully. Calculate the new volume. The difference between the old and the new volumes is the amount of soil removed during a single rainstorm from a single small gully.

A fieldtrip to a nearby stream is a valuable learning experience and can be conducted at any time during the study of this unit. The depth of study should vary with the time available and the abilities of the pupils.

Pupils may be interested in observing and explaining the following, as applicable.

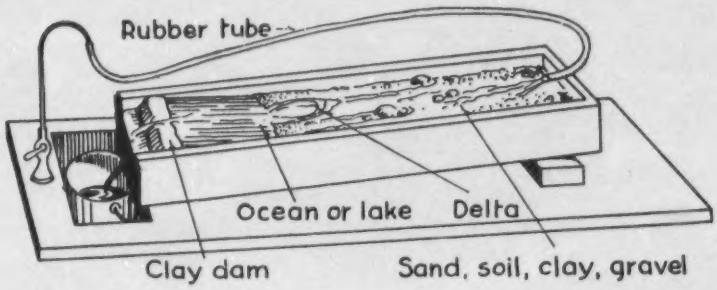
- Relationship between velocity and slope
- Shape of pebbles in the stream
- Shape of the valley
- Location of waterfalls (difference in hardness of the rock)
- Location of deltas (at entrance into a larger body of water)
- Deviation of the path from a straight line
- Where erosion on a curve of the stream is greatest (greater speed on the outside
- Flood plains

D-43. Stream Erosion and Deposition [19, 14, 2]

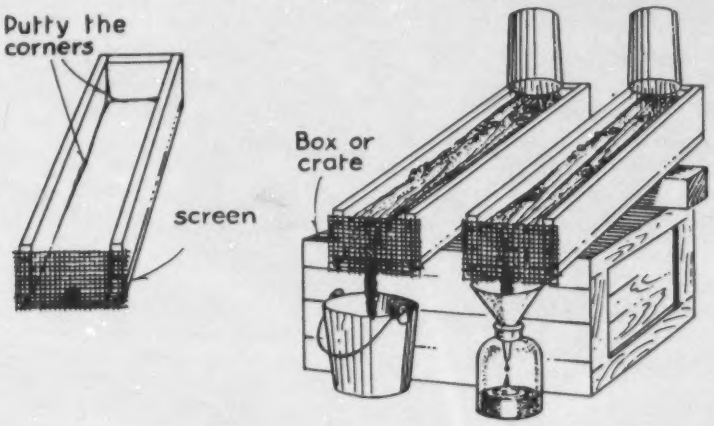
Erosion and deposition of sediments by running water can be demonstrated in the laboratory using the model shown in the diagram. Construct a wooden or metal trough about 1 meter long, 10 cm high and 20 to 40 cm wide. Use putty or neoprene on the inside corners to make it watertight. A hole for water drainage should be drilled in one end at the center near the bottom.

Elevate slightly the end opposite the hole and place several handfuls of gravel, sand, and clay in the trough. Run a rubber tube from the water source

to the elevated end of the tray to provide a constantly flowing stream. The rate of flow and the materials in the tray can be varied to produce different types of stream deposits. Be sure to catch the overflow in some sort of container to avoid clogging the drain. A small piece of copper or aluminum tubing inserted into the drain hole will facilitate drainage.



(a) A dam of clay deposited across the lower end of the tray will cause a body of water to develop a *delta*. If the dam is carefully removed, the water will drain off and show the arrangement of deposits that formed on the bottom of the body of water (see diagram below).



(b) Other features of a stream can also be shown with this tray. To illustrate stream meanders, slightly tilt the tray and start a slow flow of water across the sand and clay. Partly bury one or two pebbles or other obstructions along the course of the stream and note that meanders begin to develop at these places. Sometimes a cutoff with resulting oxbow lake will form.

(c) To illustrate an alluvial fan, make a steep pile of the mixture of sand and clay at one end of the tray. Tilt the tray and cause the water to run over the material as a stream. Where the stream reaches the bottom of the slope, sediments will be deposited in the form of a fan or cone, depending on the steepness of the slope.

D-44. Stream Load [20, 17, 9]

(a) Using the stream table from activity D-43, it is possible to observe variations in stream load. Try increasing and decreasing the slope of the stream and the volume of water. In each case, note the effect on the amount of material carried and the largest sized particle that is carried.

(b) Explore the school grounds for evidences of the transportation of soil by water. Sediment is often deposited along walks and driveways and in low places on the lawn.

(c) To show which materials in soil are carried away more readily, put some soil in a large jar half full of water. Shake the jar vigorously and then let the contents settle. Notice that the lighter and smaller particles remain suspended in water longest and hence are most easily carried away.

D-45. Stream Deposition [20, 17, 9]

(a) Raise the question of what happens to the rock particles when rocks are broken and worn away. Observe the work done by running water on and near the school grounds when it rains. Call attention to the mud and small rocks that are carried away by streams, especially where the soil is not protected by a cover of vegetation.

The importance of soil conservation should be developed at this point. Find examples of destructive erosion near the school and discuss means of preventing erosion.

Since mud remains in running water as long as it keeps moving, a great deal of rock material finds its way into lakes or oceans. When the muddy water loses its forward motion, the rock particles settle to the bottom. The larger particles settle first, followed by the smaller. During times of flood, which usually occur about once a year, enough material settles in the still water to make a layer. Each year a new layer of this sediment is deposited. As time goes on, the particles become pressed and cemented together and finally change into layers of rock.

(b) Demonstrate the way in which sediments settle in water to form layers. Stir up a little coarse sand or gravel with some finer sand and soil, add water, and pour the mixture into a battery jar or pickle jar. Note that the coarser particles settle to the bottom first, followed by the finer particles. When the water above the sediment becomes clear, siphon most of it off and add another layer in the same way. Additional layers may be added until the jar is nearly filled. The layer structure may then be clearly observed through the glass.

(c) The following procedure can be used to provide greater understanding of the relationship between settling rate and particle size. Since it involves calculations and graphing, it may not be appropriate for all pupils.

Provide pupils with containers of particles of at least four different sizes (ranging from pebbles to clay). Since determining the sizes of very small particles may be somewhat difficult for most pupils, it may be desirable to provide the diameters on the containers.

Have pupils fill a long plastic tube, closed at one end, with water. Pupils should measure and draw a line on the tube at a distance of 50 cm below the water surface.

Pupils may then drop particles of each size into the tube and measure the time for them to travel from the water surface to the line. (NOTE: Large particles may be dropped one at a time, but for clay it is suggested that about one-fourth of a teaspoon be used.) Several practice runs may be necessary. It is not necessary for pupils to empty the tube after each trial.

The following formula can be used to calculate the settling rate:

$$\text{Settling Rate} = \frac{\text{distance traveled}}{\text{elapsed time}} = \frac{50 \text{ cm}}{\text{elapsed time}}$$

If more than one trial is made for each particle size, the times may be averaged before calculating the settling rate. The results should be graphed with particle size (diameter) on the horizontal axis and settling rate on the vertical axis. Pupils should discover that there is a marked drop in settling rate as the particle size becomes very small.

D-46. Development of a River Valley [22, 14, 2]

(a) Using the stream table from activity D-43, pupils can observe that, as the water continues to flow, the stream valley becomes wider and lower. If the water is permitted to flow for a day or two, then the full cycle of stream development stages from youth to old age can be observed.

(b) A variety of stream features can be inferred from a study of topographic maps. Listed below are some stream features and maps on which they may be found.

Pupils may find it more difficult to draw inferences from topographic maps than from direct observation, photographs, or stream tables.

Feature	Quadrangle
Meanders	St. Louis, MO
Flood plains	Donaldsonville, LA
Natural levees	Leavenworth, KS
Deltas and distributaries	East Delta, LA
Alluvial fans	San Bernardino, CA Sultana, CA
Stream piracy	Kaaterskill, NY Harpers Ferry, VA
Waterfalls and gorges	Niagara Falls, NY
Water gaps	Harrisburg, PA

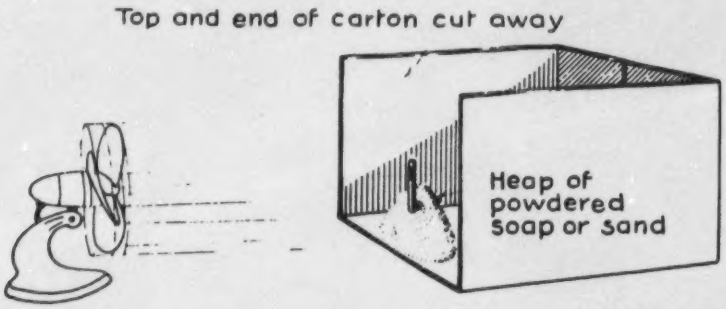
Young stream erosion	Parmela, NC Fargo, ND
Mature stream development	Charleston, WV
Old age stream development	Montgomery, LA Donaldsonville, LA Butler, MO
Drowned rivers	Cape Henry, VA
Oxbow lake	Bayou Sara, LA

D-47. Wind Erosion and Deposition [14, 2, 1]

To show that air carries sediment, set a white pan filled with water out on the windowsill. After a day or two, observe the sediment that has collected in the pan.

Try placing several pans at different heights from the ground. As a rule, most wind-transported material is carried near the ground.

D-48. The Formation of Sand Dunes [14, 2, 1]



(a) Pour a pile of dry sand on the bottom of a large carton cut away as shown in the diagram. Turn an electric fan on the pile and notice how the particles are moved. Notice that more particles are moved as the velocity of the wind increases.

Put an obstacle such as a pencil or finger in the path of the blowing sand and observe what happens. Relate this to the principle of snow fences and the behavior of sand dunes.

(b) The following topographic maps show sand dune development:

Barnegat, NJ; Moses Lake, WA; Cape Henry, VA; Yuma, CA; Lakin and Kinsley, KS; Ogalalla, NV.

D-49. Glacier Movement [14, 2, 1]

Glaciers move downslope under gravity on a thin film of water. Demonstrate that pressure due to the overlying ice melts the ice below. Place two fresh

ice cubes on a slightly inclined surface and cover each with an asbestos board. Place a heavy weight on one and a light weight on the other. Observe that the cube with the heavy weight melts faster and slides down the incline sooner than the cube with the light weight.

D-50. Glacier Erosion [22, 14, 1]

Rub a fresh ice cube across any surface that is not too hard. Then dip the cube into sand and show how ice can now scratch the same surface.

D-51. Glacier Features [14, 2, 1]

(a) In many parts of New York State, it is possible to take a nearby field-trip to observe glacier features such as moraines, outwash plains, U-shaped valleys and drumlins.

(b) Photographs, slides, films, and filmstrips can be used to illustrate a variety of glacial features.

(c) The following is a listing of topographic maps illustrating glacial features.

Feature	Quadrangle
Drumlins	Weedsport, NY Palmyra, NY
Eskers	Saranac Lake, NY Passadumkeag, ME Rouses Point, NY Fowlerville, MI
Kettles Terminal moraine Outwash plain Kettle lakes Kames	Brooklyn, NY Hempstead, NY
Finger Lakes	Watkins, Geneva, Penn Yan, Hammondsport, Naples, NY
Aretes Matterhorn peaks Hanging valleys Cirques Tarns U-shaped valleys	Mount Whitney, CA Chief Mountain, MT

D-52. Wave Motion

(a) Fasten securely one end of 5 or more feet of clothesline. Snap one end. Note the motion of the wave and the motion at any point on the clothesline. A slinky can be used even more effectively than a clothesline if one is available.

(b) Wave motion can also be observed using a glass baking dish or ripple tank partially filled with water. Float a cork at one end. At the other end, strike the water surface steadily with a flat piece of wood or plastic. This will generate waves. The motion of the waves can be observed looking downward and through the side of the dish. The motion of the cork indicates the motion of the water in the wave.

It can be observed that the water moves up and down as the wave front moves forward.

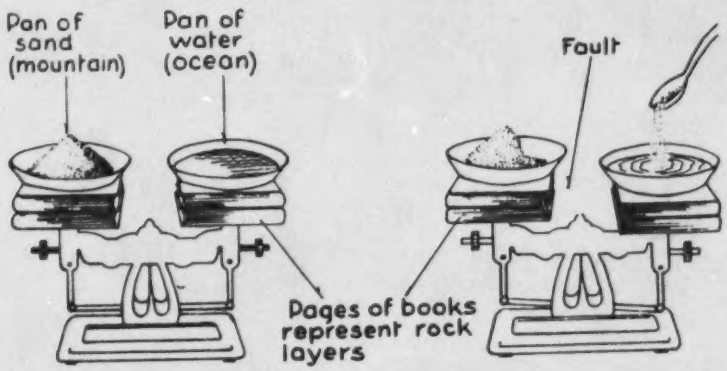
D-53. Shoreline Features [14, 2, 1]

(a) Pupils living near coastlines can observe a variety of features caused by wave action.

(b) The following topographic maps illustrate some shoreline features:

Submerged coast	Boothbay, ME Bar Harbor, ME
Emerged coast	Fire Island, NY Atlantic City, NJ Lake Como, NJ
Offshore bars	Ocean City, MD Long Beach, NJ Palm Valley, FL
Spits Hooks Lagoons Marshes	Moriches, NY Provincetown, MA Hampton, VA
Wave-cut cliffs	Oyster Bay, NY Wellfleet, MA

D-54. Isostasy [19, 14, 2]



To show how accumulated sediments may cause faulting, balance two books close together on the two arms of a platform balance. The pages of the books will represent rock layers. On one book set a pan of sand to represent a mountain. On the other set a pan of water to represent an ocean. Show sedimentation by taking a teaspoonful of sand from the mountain and dumping it into the ocean. This disturbs the balance of the earth's crust and causes a fault (earthquake).

D-55. Continental Drift [16, 14, 2]

(a) Provide pupils with cutout models of the continents and a world map. Have them attempt to move the continents so they "fit together." Mark off three or four locations along the eastern coast of North and South America to represent particular rock formations. Have pupils predict where they would look on other continents to find these rock formations in support of the continental drift theory.

(b) Drop a few crystals of potassium permanganate into one corner of a beaker filled with water. Heat the beaker with a bunsen burner placed below the crystals. As the water becomes heated, the dye can be observed to rise, travel across the surface, and sink at the opposite side. The rising and sinking dyed water can be related to the convection cells in the mantle.

(c) Have pupils look through magazines, recently published textbooks, and reference books to find examples of rock formations that scientists have correlated from different continents.

D-56. Folding of Rock Layers [22, 14, 2]

To show what happens to horizontal stratums of sedimentary rock when they are compressed laterally, stack several thin sheets of colored plasticine on each other. Then place one hand near each end of the stack and push toward the middle. The stacked materials form a hump or mountain. Slice the ridges crosswise with a knife to show the curved rock layers (synclines and anticlines).

D-57. Inferences from Fossils [22, 14, 1]

Discuss some of the following questions and demonstrate when appropriate.

- How can a fossil imprint be formed in mud?
- How can a fossil be formed in ice?
- How can a fossil be formed in amber - the fossilized resin of certain trees? (Relate to animals sealed in a clear plastic.)
- If an animal dies today, how can all or a portion of it be preserved from decay or destruction by other animals? (Burial and freezing.)
- If an animal dies, how long is it before it decays or its bones are moved?
- How can you tell the shape of the object that formed an imprint?
- How can you estimate the weight of the object that formed an imprint?

- How can you estimate the length of a dog from the imprints of its feet? (Relate to estimates of the length of prehistoric animals.)

- World War I is known to have lasted about 4 years. If an undated newspaper clipping were found which discussed some of this action as occurring "today," could you estimate within four years the date on which the paper was printed? (Relate to index fossils which are known to have existed for a brief period of time, but with wide horizontal distribution.)

- How many fish are normally found out of water? If fossils of fish, clams, oysters, and starfish are found, where were they originally formed as fossils?

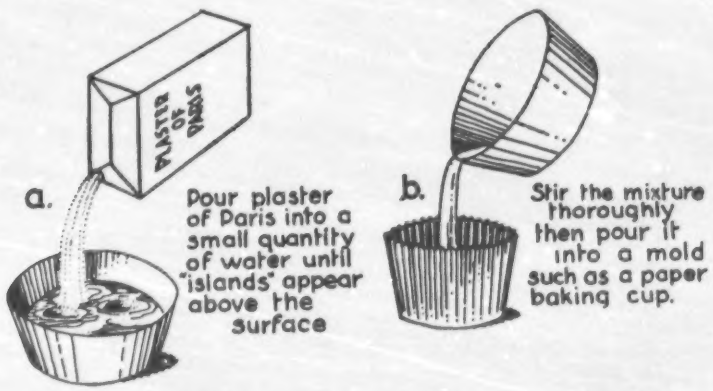
D-58. The Formation of Fossils [22, 14, 2]

The following techniques can be used to illustrate how fossils are formed:

(a) Demonstrate the making of a plaster of Paris cast. First, make a rough estimate of the amount of plaster of Paris mixture desired and pour one-third of this amount of water in a cup, jar, or can. Sprinkle plaster of Paris into the water *without stirring* until small islands appear above the surface. This method will give the right proportion of plaster of Paris and water.

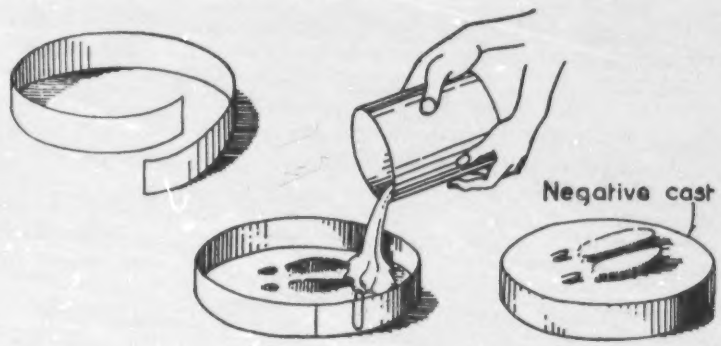
Now stir the mixture gently with a stick or spoon until it is smooth. It should have the consistency of melted ice cream or pancake batter. Pour the mixture into a greased mold or paper inserts used for muffins. The mixture will soon harden because the plaster of Paris united chemically with the water.

If paper baking cups have been used they can be removed easily from the casts because they are coated with paraffin. Such casts may be painted and decorated as desired and make attractive paper weights.


PLASTER OF PARIS
a.
Pour plaster of Paris into a small quantity of water until "islands" appear above the surface
b.
Stir the mixture thoroughly then pour it into a mold such as a paper baking cup.

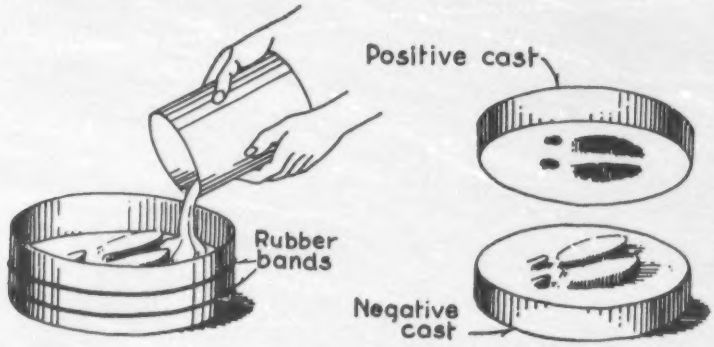
(b) With care, excellent casts of animal tracks can be made with plaster of Paris. If wild animal tracks are not found, the footprint of a cat or dog may be used to illustrate this procedure. When the track of an animal is seen in the mud, mark it with a stick and look for others. After selecting the clearest track carefully remove any debris that has fallen into it. Then make

a paper collar and press it into the mud around the track, fastening the ends together with a paper clip. Next pour plaster of Paris mixture slowly into the track, allow it to set for about 30 minutes and remove the cast carefully. Clean the cast under a faucet the following day when it is harder. A cast made in this way will of course be a negative of the footprint.



(c) Positive casts can be made from negatives in the following way. First brush the negative with a thin layer of vaseline or melted paraffin. Wrap a strip of heavy paper or cardboard around the negative and fasten it with a rubber band. Pour plaster of Paris batter into this collar to a depth of at least an inch and allow it to dry for a half hour or more.

To separate the positive cast from the negative cast remove the collar and insert a knife between the two casts. Next smooth the sides and back with a knife and sandpaper. The positive cast can then be painted or given a coat of shellac to preserve it.



(d) Cover a leaf with vaseline and lay it on a pane of glass. Around the leaf place a circular strip of paper or linoleum and press modeling clay against this collar to hold it in position. Now pour about one-half inch of plaster of Paris batter over the leaf. In about 15 minutes the paper and leaf can be removed and an excellent leaf print will result. This illustrates well the process of the formation of one type of fossils.

Look for leaf prints in soft coal. Imprints of fern leaves are commonly found.

(e) Cover a shell such as a clam shell or scallop shell with vaseline and pour wet plaster of Paris on it as was done in making a leaf print.

D-59. Inferences From the Rock Sequence [21, 9, 14]

Demonstrate and discuss the following as appropriate.

- On a flat surface, place in a pile three or more strips of colored modeling clay or colored paper. Assume that the order was not changed in any way after placing them down. Which strip or sheet was placed on the surface first? Next? Next? (Relate to the oldest rocks being at the greatest depth in a sequence unless overturning or thrust faulting has taken place.)

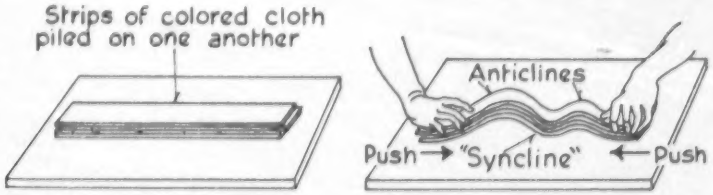
- Make a hole through one or more of the strips or sheets with a dowel, scissors, and so forth, starting from the bottom, and leave the dowel in place. Ask pupils to reconstruct the order in which the events occurred. Liken the object to an igneous intrusion to show why the intrusion occurred later than the layer it intruded.

D-60. Inferences From the Position of Rocks [22, 14, 1]

Several inferences may be obtained by experimenting with a sheet of modeling clay or with a stack of several sheets of colored paper (or strips of colored cloth) as shown below:

(a) Hold two opposite sides. Ask a pupil to push up near the center of the sheet. Note the domed shape. (Some mountains are formed by an igneous intrusion doming up layers of rock.)

(b) Hold two opposite sides as shown below. Exert pressure by moving the hands together. Note that the paper can be distorted into upfolds (anticlines) and downfolds (synclines) resembling water waves when viewed from the side. Have you ever seen rock layers distorted like this? (Such features may often be seen in road cuts.)



(c) Prepare a model of an anticline as in (a) above by using modeling clay (or any substance that will hold its shape). Cut horizontally across the anticline to remove the top and thus leave only the sides. Display this model to pupils and ask them how to determine the probable height and location of the highest spot before it was removed. (Extending the sides that remain will give a close approximation.) Relate to a way to determine the former height of this type of mountain when only some of the sides remain.

(d) Glue together three or four sheets of cardboard or use several strips of colored modeling clay. Mark each layer for easy identification. Cut the sheets vertically; place the two parts side by side, but with one part lower than the other; hold them together in some way. Present the completed model for discussion. Can you identify similar layers? (They are marked.) How could they have been formed so that the same layer occurred at two different levels? (They probably formed at the same level and one part slipped down or up.) Evidences such as this indicate a crustal movement occurring in earthquakes and in the formation of some mountains.

D-61. Geologic Time Scale [13, 12, 7]

Pupils tend to be confused about the time span of geologic history. One technique that helps to create proper perspective is to plot events from the geologic past on a time line. This can be done using adding machine tape and a scale of 1 meter = 1 billion years. Determining the scale may be somewhat challenging for most pupils. It may be desirable to assign this task to a few interested pupils or to provide the scale. The following is a sample list of events from the geologic past. (Also, see Appendix B; pages 78-9 [8], [9].)

YEARS BEFORE THE PRESENT (APPROX.)	EVENT
10 ——>	Man first lands on the moon
100 ——>	The automobile is invented
500 ——>	Columbus discovers America
5,000 ——>	Early Egyptian civilization
20,000 ——>	Most recent ice sheet advance
50,000 ——>	Modern man appears
2,000,000 ——>	Earliest man
60,000,000 ——>	Beginning of the Cenozoic Era (the rise of mammals)
200,000,000 ——>	Beginning of the Mesozoic Era (earliest dinosaurs)
400,000,000 ——>	First land plants and animals
600,000,000 ——>	Beginning of the Paleozoic Era (earliest abundance of marine life)
4,500,000,000 ——>	Formation of the earth

Use the time scale to discuss with pupils the relative intervals between events. For example, it is interesting to compare the time span between the first appearance of modern man and the discovery of America and between the discovery of America and the first landing on the moon.

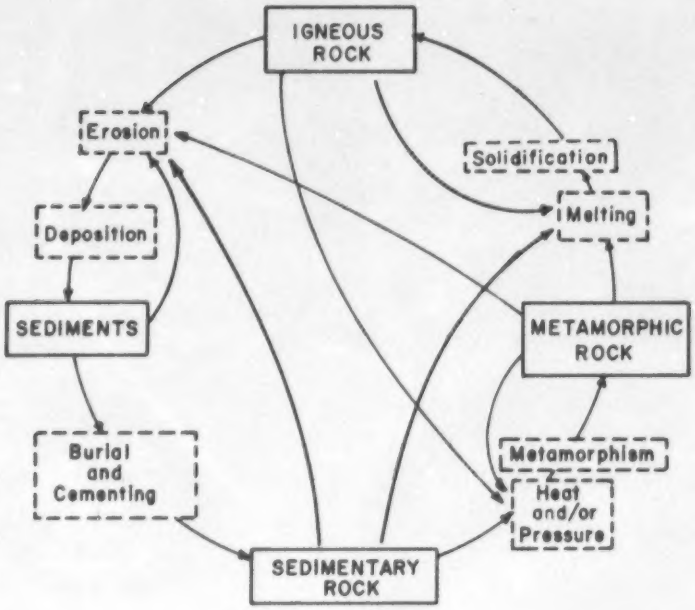
[1] IDENTIFYING CHARACTERISTICS OF SOME COMMON MINERALS

Mineral	*Hardness*	*Breakage*	*Streak*	*Luster*	*Usual Color*	*Specific Gravity*	*Special Characteristics*
Quartz	7 (h)	shell-like fracture	white or colorless	glassy	colorless, variety	2.6+	6-sided crystals
Feldspar, Orthoclase	6 (h)	2 cleavages at right angles	white	glassy	white, gray, pink	2.5+	
Mica, Biotite	2.5+(s-fh)	1 perfect cleavage	white	glassy	dark green, black to brown	2.8+	
Mica, Muscovite	2+(s)	1 perfect cleavage	white	glassy	colorless,(on thin sheets)	2.8+	elastic sheets, flaky
Calcite	3 (s-fh)	3 cleavages	white	glassy to earthy	white to colorless	2.7	effervesces in HCl
Kaolinite	2+(s)	1 cleavage	white	dull, earthy	white	2.6+	
Garnet	6.5-7.5(h)	poor cleavage	scratches plate	glassy	red	3.5-4.3	brittle
Gypsum	2 (s)	cleavage in 3 directions	white	glassy to silky	colorless to white, gray	2.3	
Halite	2.5 (s)	perfect cubic cleavage	white	glassy	colorless to white	2.1+	
Talc	1 (s)	perfect cleavage	white	greasy	apple green, gray, white	2.7	feels soapy
Magnetite	6 (h)		black	metallic	black	5.1+	strongly magnetic

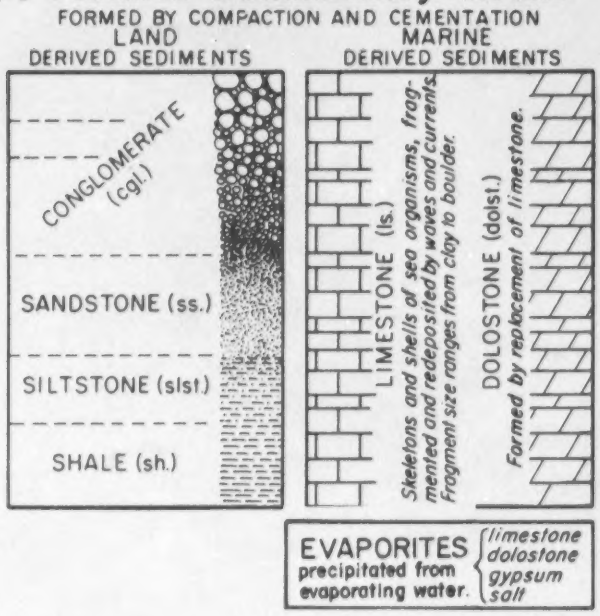
[1] IDENTIFYING CHARACTERISTICS OF SOME COMMON MINERALS *(Continued)*

Mineral	*Hardness*	*Breakage*	*Streak*	*Luster*	*Usual Color*	*Specific Gravity*	*Special Characteristics*
Hematite	5.5-6.5 (fh-h)	uneven fracture	red-brown	metallic	reddish brown to black	5.2+	
Limonite	5-5.5 (fh)	shell-like or earthy fracture	yellow brown	glassy	dark brown to black	3.6+	
Galena	2.5 (s)	perfect cubic cleavage	lead gray	bright metallic	lead gray	7.6	very dense
Bauxite	1-3 (s-fh)		varies	dull to earthy	white to gray	2-2.5	clay-like odor
Pyrite	6-6.5 (h)		Greenish to brown-ish black	metallic	pale brass yellow	4.8+	
Graphite	1-2 (s)		black	metallic to dull earthy	black	2.1+	marks paper easily, greasy

[2] ROCK CYCLE



[3] Common Sedimentary Rocks



[4] Generalized Landscape Regions of New York State

[5] IDENTIFYING CHARACTERISTICS OF SOME COMMON ROCKS

ROCK	CONSTITUENTS	IDENTIFYING CHARACTERISTICS
Igneous		
Granite	Quartz, feldspar	Coarse-grained, light-colored, relatively low density
Gabbro	Plagioclase feldspar, pyroxene, and sometimes olivine	Coarse-grained, dark-colored, relatively high density, common to the Adirondacks
Basalt	Feldspar	Fine-grained, dark-colored, low density, often has cavities lined with olivine
Pumice	Individual minerals not visible	Glassy, porous, silky, glass fibers, usually light-colored, floats in water
Obsidian	Individual minerals not visible	Glassy, shell-like fracture, dark-colored
Sedimentary		
Conglomerate	Cemented, rounded gravel with sand	Coarse particles cemented resemble concrete
Sandstone	Cemented sand grains, usually quartz	Porous, gritty "feel," usually does not bubble with hydrochloric acid, various colors
Shale	Compact mud or clay particles (kaolinite)	Impervious, earthy odor, usually does not bubble with hydrochloric acid, brittle

[5] IDENTIFYING CHARACTERISTICS OF SOME COMMON ROCKS *(Continued)*

ROCK	CONSTITUENTS	IDENTIFYING CHARACTERISTICS
Limestone	Compact limey mud (calcite)	Impervious, bubbles with hydrochloric acid, various colors
Dolomite	A carbonate of calcium and magnesium	Impervious, less likely to bubble with hydrochloric acid than limestone
Metamorphic		
Gneiss	Quartz, feldspar, mica or hornblende	Minerals arranged in coarse parallel bands; resembles granite; formed from granite
Schist	Mica, quartz, garnet hornblende, garnet	Minerals arranged in thin parallel bands; can be split; has wavy uneven surface, formed from sedimentary or igneous rocks
Slate	Clay minerals	Slaty cleavage; splits into smooth, flat surfaces; red, gray, green or purple; formed from shale
Quartzite	Quartz	Very crystalline, hard, dense; formed from sandstone
Marble	Calcite	Crystalline, granular, bubbles with hydrochloric acid, white or gray or streaked with colors due to impurities (iron, carbon); does not react with hydrochloric acid

[6] Some Common Fossils

KEY TO DIAGRAM

1. Graptolites
2. Corals
3. Bryozoans
4. Brachiopods
5. Grastropods
6. Cephalopods
7. Crinoid
8. Trilobite
9. Pelecypods

[7]

I COARSE EQUIGRANULAR > 2MM.

H	F	
HARDER THAN KNIFE	DIRECTED	GNEISS - Alternate bands of light and dark minerals, chiefly feldspar, quartz, with ferromagnesian minerals. When fine grained, gneiss may resemble schist, but the mica content is less in gneiss than in schist. QUARTZITE - See below.
	RANDOM	PLUTONIC IGNEOUS ROCKS of wide variety. Specifically these are named on the basis of mineral ratios between quartz, orthoclase and plagioclase feldspars, and ferromagnesian minerals. Common varieties are GRANITE - Feldspar, chiefly orthoclase, with quartz. GABBRO - Plagioclase feldspar with ferromagnesian minerals, no quartz. PEGMATITE - Abnormally coarse-grained igneous rock, commonly with feldspar and quartz. QUARTZITE - Metamorphic, quartz grain rich sandstone with recrystallized quartz groundmass; glassy luster; rock fractures through grains and groundmass alike.
SOFTER THAN KNIFE	DIRECTED	RECRYSTALLIZED LIMESTONE - Recrystallization, usually resulting in an increase in grain size, may constitute the entire specimen, or occur in patches throughout a fine-grained specimen. Calcite cleavage is obvious in recrystallized areas. Banded marbles and evaporites - See below.
	RANDOM	MARBLE - Higher luster and usually lighter color than limestone. Cleavage on calcite is obvious. Dolomitic marbles may be distinguished by their failure to effervesce in HCl except when powdered. Flow banding in some marbles will produce a directed fabric. Ophicalcite - Marble with serpentine grains. EVAPORITES - Chemical rocks including Halite, Gypsum, Anhydrite. Apply mineral tests to identify. Some evaporites may be banded.

[7]

2 FINE EQUIGRANULAR < 2MM.

H	F	FRAGMENTAL	CRYSTALLINE
HARDER THAN KNIFE	DIRECTED	SANDSTONES - Grains easily seen with naked eye. Mineralogical identification of grains is required to provide a specific name. Varieties are: QUARTZITIC SANDSTONE- Very rich in quartz grains; cemented. Rock fractures around the grains. ARKOSE - Reddish, tan; abundant feldspar. SUBGRAYWACKE - Intermediate in properties between quartzitic sandstone and graywacke. GRAYWACKE - See Chart 3. SILTSTONE - Grains easily seen with lens but not easily seen with naked eye. Feels gritty.	GNEISS - Fine- grained varieties. See Chart 1. Welded tuff - Banded or flow-bedded; partly glassy, light-colored.
	RANDOM	(In small specimens, the bedding in some sandstones and siltstones may not be obvious and a random fabric might be indicated.)	Shallow intrusive igneous and extrusive volcanic rocks of wide variety. Specifically named in the same manner as the coarse-grained igneous rocks; identification is based on only that portion of the rock which is discernable with the lens. Non-specific names based on abundance of light and dark minerals are: Felsite - light-colored TRAP - dark-colored Hornfels - Fine-grained metamorphic rock with variable mineralogy.
SOFTER THAN KNIFE	DIRECTED	Oolitic limestone - Spherical or ovoid grains disseminated through the rock. Oolitic hematite - Spherical or ovoid grains disseminated through rock; may also contain small fossil fragments. Red streak and color.	LIMESTONE - Calcite cleavage usually seen as minute flashes of reflected light. Effervesces in HCl. DOLOMITIC LIMESTONE is distinguished by its failure to effervesce in dilute HCl except when powdered. Small specimens may appear to have a random fabric. HEMATITE - Red color and streak; higher specific gravity. SCHISTS - Foliated mica-rich metamorphic rocks of wide variety; may approach gneisses compositionally with increase in light-colored minerals such as quartz and feldspar.
	RANDOM		MARBLE - Some marbles are fine-grained. Apply same tests as for coarse varieties. See Chart 1. HEMATITE - See above.

[7]

3 INEQUIGRANULAR

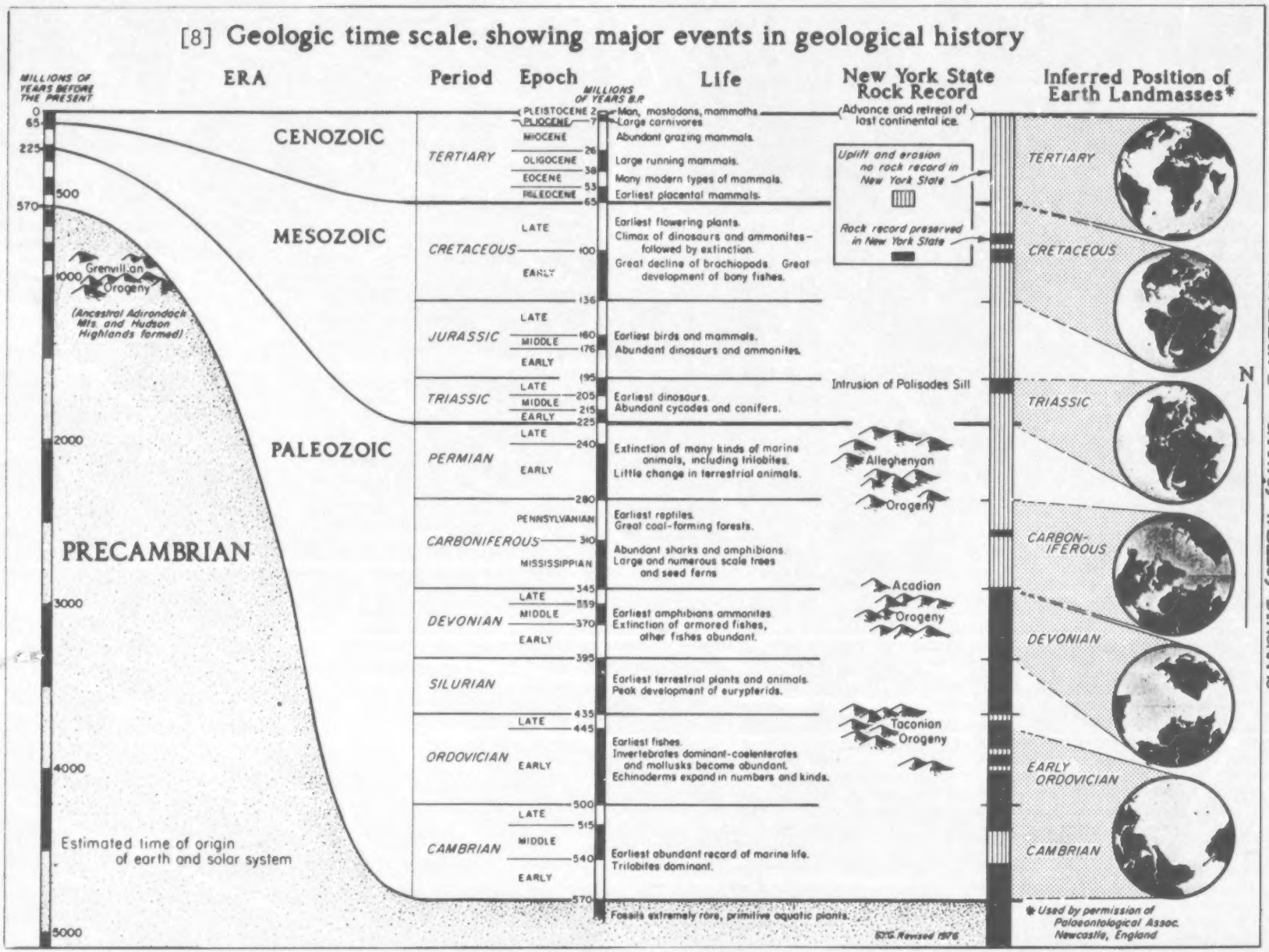
H	F	FRAGMENTAL	CRYSTALLINE
HARDER THAN KNIFE	DIRECTED	CONGLOMERATE - Rounded granules (2-4mm.) or pebbles (>4mm.) embedded in matrix of finer grains. Specifically identified on the oasis of the mineralogy of the coarse grains, as QUARTZ-PEBBLE CONGLOMERATE, MIXED-PEBBLE CONGLOMERATE GRAYWACKE - Greenish gray color; ill-sorted sandstone with quartz, feldspar, or rock fragments embedded in a matrix of rock paste. Breccia - Similar to conglomerate but with angular fragments.	GNEISS - Banded with light and dark minerals. If larger crystals of some mineral are also present, the rock is called Porphyroblastic gneiss.
	RANDOM	(Some coarse conglomerates and graywackes may appear to have a random fabric in small specimens.)	Porphyritic igneous rocks of wide variety - Larger crystals (called phenocrysts) are embedded in either a fine or a coarse-grained groundmass. Fine-grained varieties may be called Felsite porphyry - light colored. Trap porphyry - dark colored. Skarn - Coarse-grained metamorphic rock usually containing pyroxene. PEGMATITE - See Chart 1.
SOFTER THAN KNIFE	DIRECTED	Oolitic rocks - See Chart 2. FOSSILIFEROUS LIMESTONE - Variety of limestone where fossils contribute abundantly to the bulk of the rock. Limestone-pebble breccia - Angular or sub-rounded pebbles or slabs of limestone embedded in a limy or sandy matrix. Peat - Rich in plant fragments; brown color. Lignite - Brownish black, with plant fragments; intermediate between peat and sub-bituminous coal. Coquina - Abraded fossil shells and fragments; porous, open structure; loosely cemented.	SCHIST - Some schists contain crystals coarser than the micaceous groundmass (eg. tourmaline, magnetite, garnet, pyrite, etc.) RECRYSTALLIZED LIMESTONE - See Chart 1.
	RANDOM		

[7]

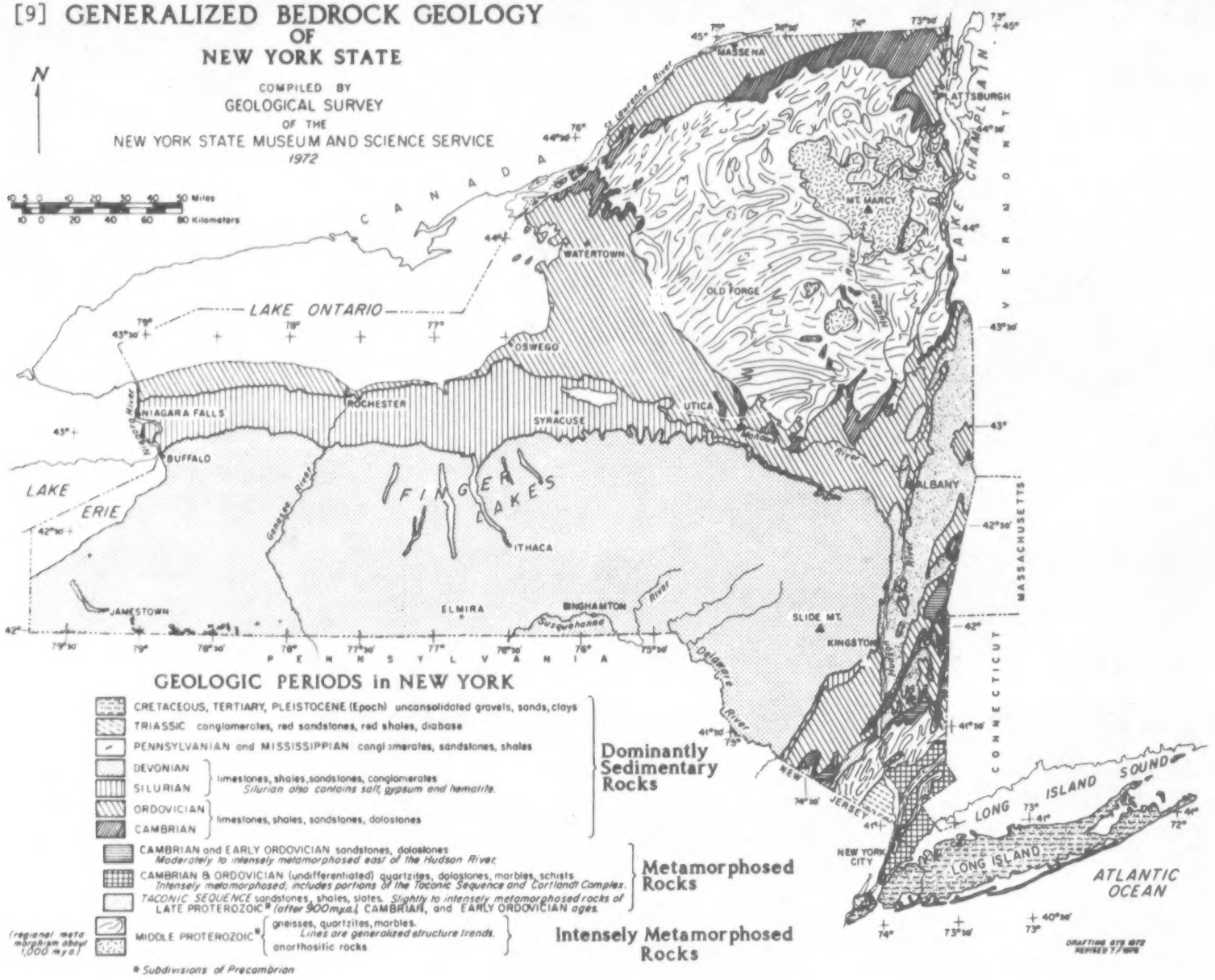
4 ULTRA-FINE-GRAINED

H	F	
HARDER THAN KNIFE	DIRECTED	NOTE Care should be exercized in recognizing, as such, fragments of large, broken crystals. Apply mineral identification tests to these specimens. Petrified wood - Dull or opaline luster; wood fiber banding.
	RANDOM	Igneous glass - Pumice - vesicular; light color; low specific gravity. Scoria - vesicular; dark color. Obsidian - compact; glassy luster; conchoidal fracture; red or black. CHERT (FLINT) - Dull luster; frequently occurs as nodules or irregular masses in limestone or chalk. Also bedded, with a directed fabric.
SOFTER THAN KNIFE	DIRECTED	SHALE - Clay-rich rock, tending to split along the bedding planes; some silt grains may be seen with the lens but shale feels smoother than siltstone. SLATE - Mica-rich rock with cleavage producing parallel, planar fractures throughout the specimen. Tends to ring when struck; slightly brighter luster than shale. PHYLLITE - Foliated, with a micaceous sheen. Grains are visible but too small to identify; intermediate in appearance between slate and schist. Serpentine - Greasy, waxy, or silky luster; greenish, frequently mottled. May be fibrous, banded, massive, or brecciated.
	RANDOM	MUDSTONE, CLAYSTONE - Clay-rich rock which does not split parallel to the bedding; blocky, irregular fracture. LITHOGRAPHIC LIMESTONE - Smooth, dense; conchoidal or irregular fracture; effervesces with HCl. Chalk - Light color; low sp. grav.; effervesces with HCl. Diatomaceous earth - Light color; low sp. grav.;no effervescence with HCl. Kaolinite - Earthy odor; light color; low sp. grav.; no effervescence with HCl. Coal (bituminous, anthracite) - Bright luster; low sp. grav.; black.

[8] Geologic time scale, showing major events in geological history



[9] GENERALIZED BEDROCK GEOLOGY OF NEW YORK STATE



GEOLOGIC PERIODS in NEW YORK

Dominantly Sedimentary Rocks

- CRETACEOUS, TERTIARY, PLEISTOCENE (Epoch) unconsolidated gravels, sands, clays
- TRIASSIC conglomerates, red sandstones, red shales, diabase
- PENNSYLVANIAN and MISSISSIPPIAN conglomerates, sandstones, shales
- DEVONIAN, SILURIAN: limestones, shales, sandstones, conglomerates. *Silurian also contains salt, gypsum and hematite.*
- ORDOVICIAN, CAMBRIAN: limestones, shales, sandstones, dolostones

Metamorphosed Rocks

- CAMBRIAN and EARLY ORDOVICIAN sandstones, dolostones. *Moderately to intensely metamorphosed east of the Hudson River.*
- CAMBRIAN & ORDOVICIAN (undifferentiated) quartzites, dolostones, marbles, schists. *Intensely metamorphosed; includes portions of the Taconic Sequence and Cortlandt Complex.*
- *TACONIC SEQUENCE* sandstones, shales, slates. *Slightly to intensely metamorphosed rocks of* LATE PROTEROZOIC* *(after 900 mya)*, CAMBRIAN, and EARLY ORDOVICIAN *ages.*

Intensely Metamorphosed Rocks

- MIDDLE PROTEROZOIC* (regional metamorphism about 1,000 mya): gneisses, quartzites, marbles. *Lines are generalized structure trends.* anorthositic rocks

* Subdivisions of Precambrian